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A

TREATISE

ON

BUILDING in WATER.

IN TWO PARTS.

PART I.

Particularly relative to the Repair and Re-building of ESSEX-BRIDGE, DUBLIN, and Bridge-Building in general, with Plans properly ſuited to the Re-building of ORMOND-BRIDGE.

PART II.

Concerning an Attempt to contrive and introduce quick and cheap Methods, for erecting ſubſtantial Stone-buildings and other Works, in freſh and ſalt Water, quaking Bogs or Moraſſes, for various Purpoſes; fully laid down and clearly demonſtrated, by TWELVE PRACTICAL PROPOSITIONS, but not in any Caſe exceeding ten Fathom deep: Together, with a Plan for a ſpacious and a commodious Harbour for the DOWNS in ENGLAND, projecting to 20 Feet deep at low Water.

Principally addreſſed and peculiarly adapted to young and unexperienced Readers.

Illuſtrated with ſixty-three COPPER-PLATES.

By GEORGE SEMPLE.

Bid *Harbours* open, *public Roads* extend,
And *Temples* worthier of the GOD aſcend;
Bid the *broad Arch* the dangerous Flood contain,
The *Mole projected*, break the roaring Main;
Back to his Bounds their Subject *Sea* command,
And roll obedient *Rivers* thro' the Land:
Theſe Honours, Peace to happy BRITAIN brings;
Theſe are Imperial Works, and worthy Kings.

POPE's Epiſt.

DUBLIN:

Printed for the AUTHOR, by J. A. HUSBAND, (No. 28.) ABBEY-STREET.
M.DCC.LXXVI.



TO

THE KING.

SIR,

YOUR Majeſty has been conſtantly conſidered as the Friend and Patron of the *Sciences* and the *Arts*. The eminent Virtues that beam from *Britain*'s Throne, would have rendered a private Station illuſtrious, and dignified the Scholar and the Man. To whom then can I, with ſuch Propriety, inſcribe theſe Sheets, as to a Monarch, who is peculiarly intereſted in the Subject of the moſt important Part of them, that of a "Plan for a commodious Harbour in the *Downs?*"---I lay them, with the utmoſt Deference and Humility, at your Majeſty's Feet. They are the Fruits of a cloſe and unremitted Application of twenty-four Years. Should they be thought deſerving the ſlighteſt Attention of your Majeſty, or induce any of your Majeſty's Servants to think the Plan I have deſigned, may be conducive to your Majeſty's Service; I ſhall think thoſe Years the beſt employed in my Life, and in the Evening of my Days, reflect with a peculiar Degree of Satisfaction, I have not lived in vain.

I am, with the moſt dutiful and profound Reſpect,

Your Majeſty's

Moſt loyal and faithful Subject and Servant,

DUBLIN,
October 2d. 1775.

G. SEMPLE.



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BUILDING in WATER.

PART I.

Particularly relative to the Repair and Re-building of *Eſſex-bridge*, *Dublin*, and Bridge-Building in general, with Plans properly ſuited to the Re-building of *Ormond-bridge*.

CHAP. I.

Concerning the Temporary Repair of Eſſex-bridge.

IN the latter end of May, 1751, I accidentally met with Mr. *Prior* at his Grace the Lord Archbiſhop of *Dublin*'s, where I heard him very pathetically lament the Loſs and Inconvenience the Public ſuſtained, by being near four Months deprived of the Uſe of *Eſſex-bridge*: On which his Grace enquired further into that Matter, and was informed, that there were then two or three Schemes lying before the Corporation of the City; one of which, was to repair it with Timber in five Months for 500 *l.* another with Stone, within ſix Months for 800 *l.* &c. &c.

Mr. *Prior* then earneſtly requeſted my Opinion, to which, I replied, That as I had not taken any particular Notice of it, I could not preſume to give my Sentiments; but not being ſatisfied with that Anſwer, he preſſed me to tell him what I thought of it. On which, I told him, that I did not apprehend there was any Difficulty in making an effectual temporary Repair with Timber; and to further Queſtions, I inſtantly anſwered, that I believed, it might be done within ten Days, for about one hundred Guineas.

On this, he immediately acquainted Alderman *John Cooke*, then Lord Mayor, and from that Time Mr. *Prior* (living contiguous to me) made me frequent Viſits, and at length prevailed on me with ſome Reluctance to engage in it. Accordingly, I began to

examine the whole Structure, and to prepare for the temporary Repair. See Plate I.

EXPLANATION of PLATE I. *Scale* 30 *Feet to* 1 *Inch.*

This Plate represents the Plan of the Superstructure, as I found it on the 20th July 1751. Wherein Note,

A. Carriage Way, 20 Feet 5 Inches Broad. B. Foot-way, 9 Feet 5 Inches, on an Average. C. Pedestal of the Equestrian Statue of King George I. D. The Pier that fell down, and caused the Breach in the Carriage-way. See Plate II.

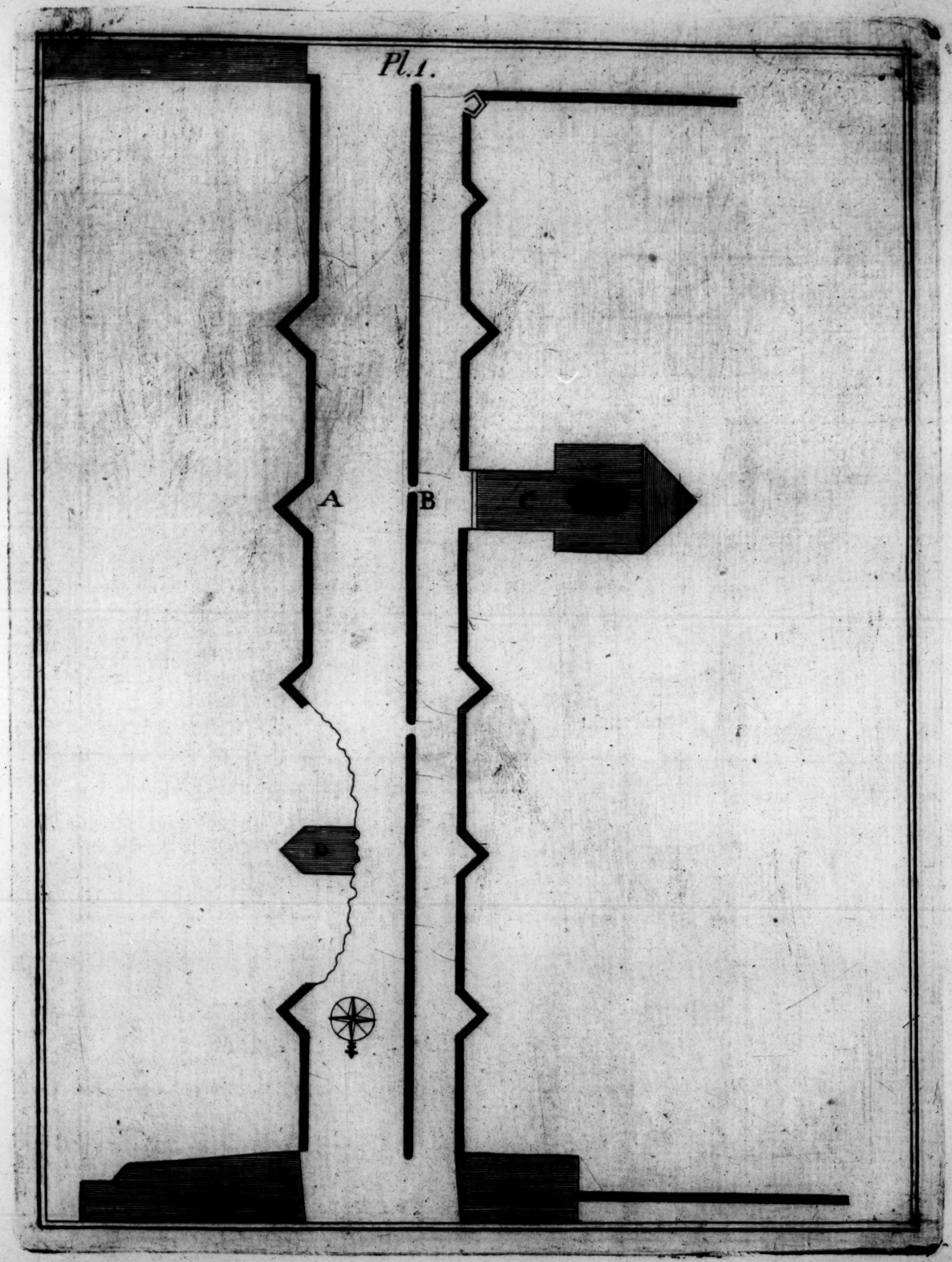
EXPLANATION of PLATE II. *per the same Scale.*

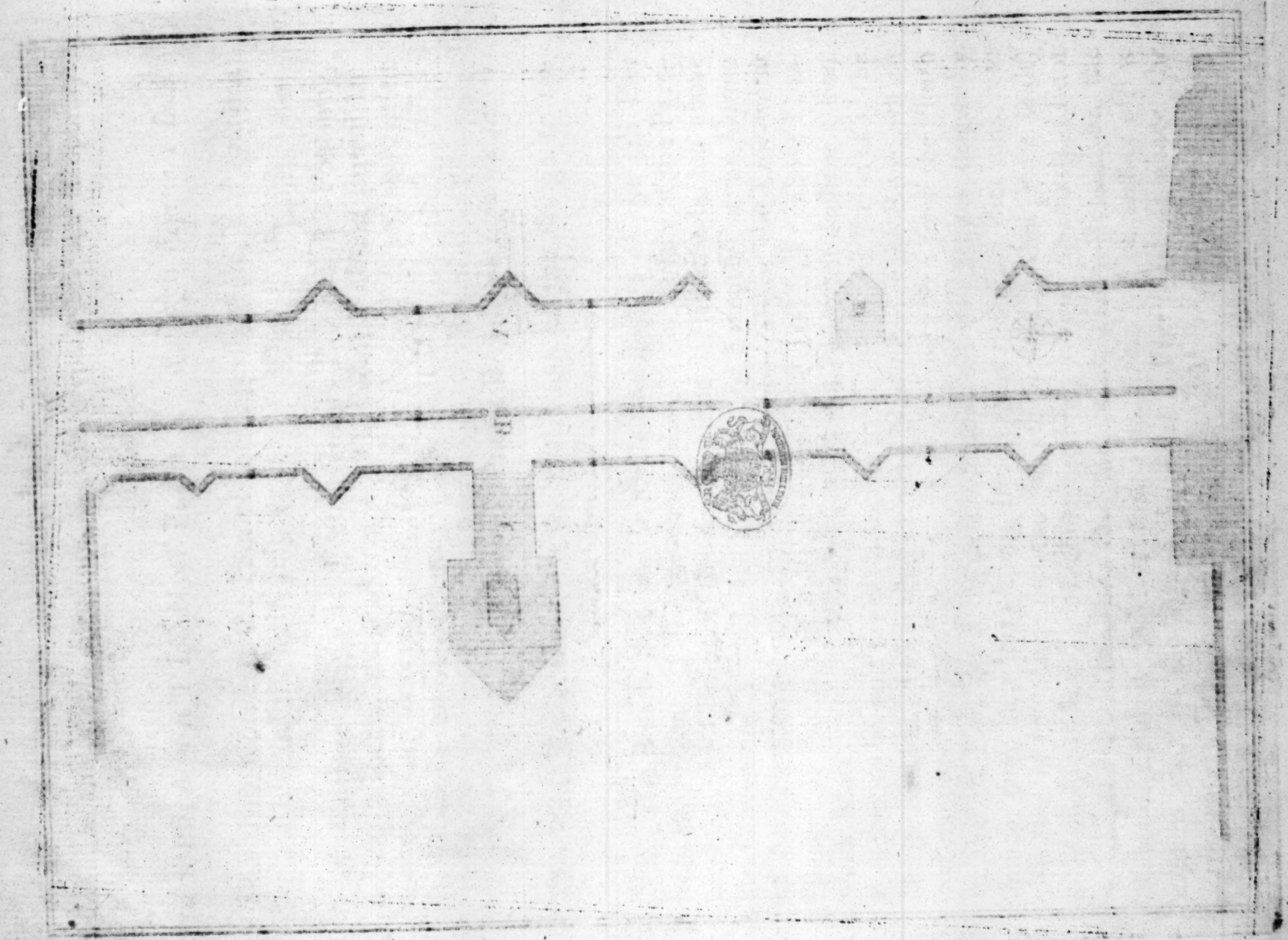
This Plate Fig. 1. represents the East Front of the Bridge to the Surface of the Pavement.

E. The Breach that was made by the Failure of the 5th Pier from the South. F F. Low-water Mark. G. Surface of the Pavement at the Corner of the Excise-office, 24 Feet 2 Inches above the Low-water Mark. H. Surface of the Pavement at the Corner of Mr. Newton's-Shop, 19 Feet 4 Inches above the Low-water Mark. I. Summit of the Pavement 26 Feet 8 Inches above Low-water Mark. N. B. From this Place the Pavement declines 2 Feet 6 Inches to G. and 7 Feet 4 Inches to H. whence it seems as if the Bridge had settled somewhat into the North Bed of the River, which put me upon Examining. K. A level Line taken from the Plinth of the 2d Pier, on a Supposition that all the Arches originally sprang from that level Line: If so, then the third Pier sunk into the Bed of the River (on the Surface of which they were built) 6 Inches; the fourth, 8 Inches; the fifth, 1 Foot; the sixth, 1 Foot 7 Inches. L. Represents that this South Pier is rebuilt on the Ruins of a former Arch that had fallen down. The Surface of the highest Part of the Ruins is about 4 Feet 6 Inches above the Low-water Mark, consequently obstructed so much of the Water-way, and made it incline to the Northward.

In

Pl. 1.





Pl. 2.

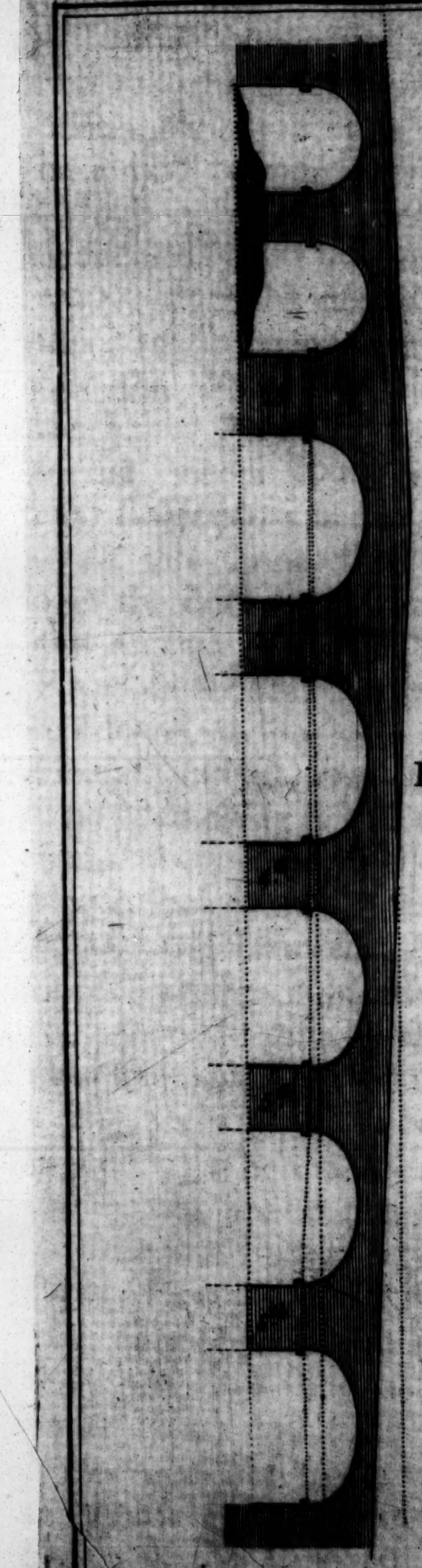


Fig. 2.

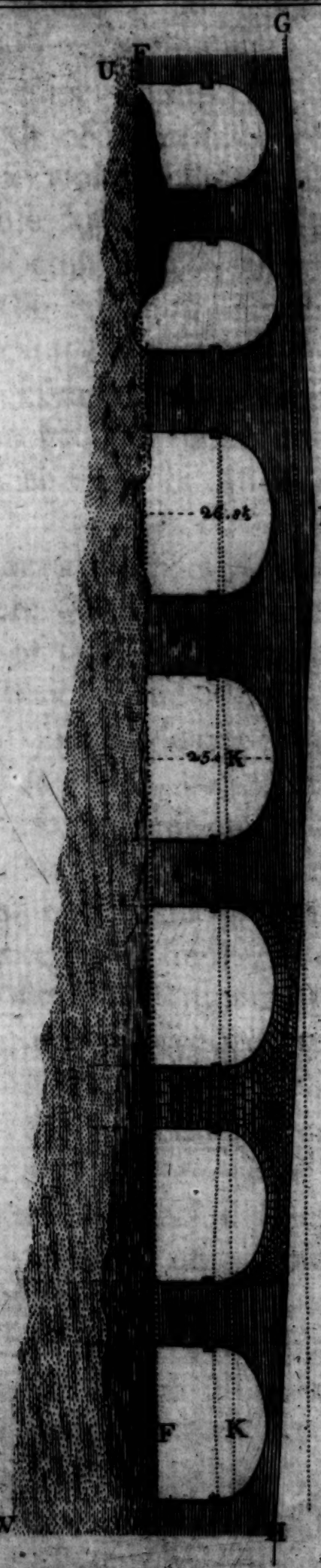


Fig. 1.



In the Year 1676, Sir *Humphrey Jervis* began to build this Bridge (of the Stones of *St. Mary's-Abbey*) and in about eleven Years after, *viz.* On the 4th and 5th of *December* 1687, there happened a very great Rain, and a violent Storm at E. S. E. (which is the likelieſt Point to cauſe high Tides in this River, becauſe both Tide and Land-flood coming together, generally occaſions the Tides riſing higher in the River than ordinary) and this high Tide meeting with an exceeding high Flood in the River, roſe the Water to ſuch a prodigious Height, as quite overflowed the lower Parts of the City: In ſome Houſes the Water roſe up to the Parlour Floor, and on ſome of the Quays much higher, ſo that Boats plied in the Streets.

At this Time there happened to be a Hackney-coach driving over the Bridge, but providentially there was no Body in the Coach, and as they were juſt on the Crown of that Arch, the Bed of the River under that Pier being carried away by the Floods, the Pier fell down, and ſo down came the Arch, Coach, Coach-man and two Horſes, and all together were ſwept down to the Watering-ſlip. The Man clung faſt to the Coach-box, ſometimes under and ſometimes above Water, till they came to the Slip, where one of the Horſes broke his Traces and ſwam out, but the Man and the other Horſe were drowned. And as this happened in the Midſt of Winter, they certainly could not conveniently get the Ruins at that Time removed, therefore, they only juſt rough-levelled them, and built the new Pier upon them.

Fig. 2. by the ſame Scale, repreſents the Weſt Side of the Bridge inverted: Wherein obſerve, that the Plinth of the third Pier from the South, has on this Side ſunk from the level Line about 1 Foot; the fourth 1 Foot 7 Inches; the fifth 2 Feet 1 Inch, and the ſixth Pier 3 Feet 6 Inches; ſo comparing theſe with the ſame on the Eaſt Side reſpectively, the Cauſe of this Weſt Side ſinking more than the Eaſt Side, is obvious, *viz.* That the Foot-way being lately built, and the Workmen taking down the Cut-waters to Low-water Mark, in order to join the Piers of the Foot-way cloſe to it, built Part of the Piers of the Foot-way on Part of the Foundation of the Cut-waters, and the reſt of them on the naked Bed

of the River. This was the Cauſe of the Foot-way being opened, and ſeparated about eight Inches from the Bridge, and the Ground being much ſofter at the North than at the South end, it yielded and ſunk ſo much the more under it.

EXPLANATION *of* PLATE III. *or Temporary Repair, laid down by a Scale of* 8 *Feet to* 1 *Inch.*

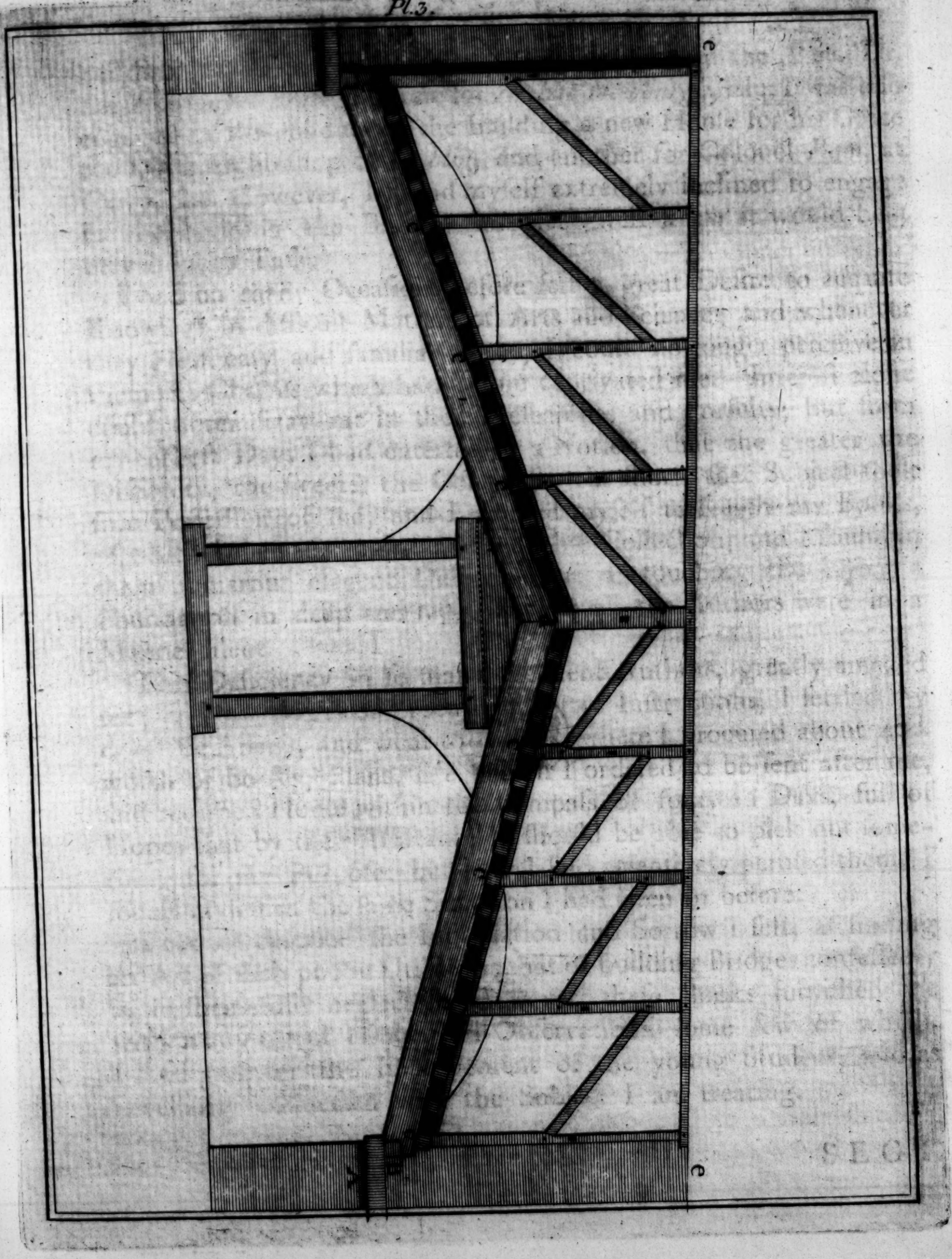
All that I found neceſſary for this Purpoſe, was to clear and ſquare the Breach down to the Plinths A. and thereon to bed the Plates B. on which I lodged the Ends of two Brace-beams of 16 Inches Square, and in like Manner two more Inwards covered with Joiſts, and floored with three Inch Plank, under which I previouſly erected two Frames to ſupport them at their joining; and as I was aware that the outward Frame was in great Danger of being ſwept away by a Flood, I did not engage them to the Brace Beams, which in Truth ſtood in no Need of their Support. The eight Joiſts marked c. and the Crown Beams d. projected from three to five Feet, to ſuſtain the Feet of the outward Braces. e e. Is the Top of the Parapet Wall, and I hope that bare Inſpection is ſufficient to explain the Reſt. On the 30th of the ſame Month of July, I had compleated the whole, that is, on the 10th Day I laid it open for Carriages, and the Coſt did not exceed the Sum of 100 Guineas, as I had unpremeditatedly mentioned to Mr. *Prior*.

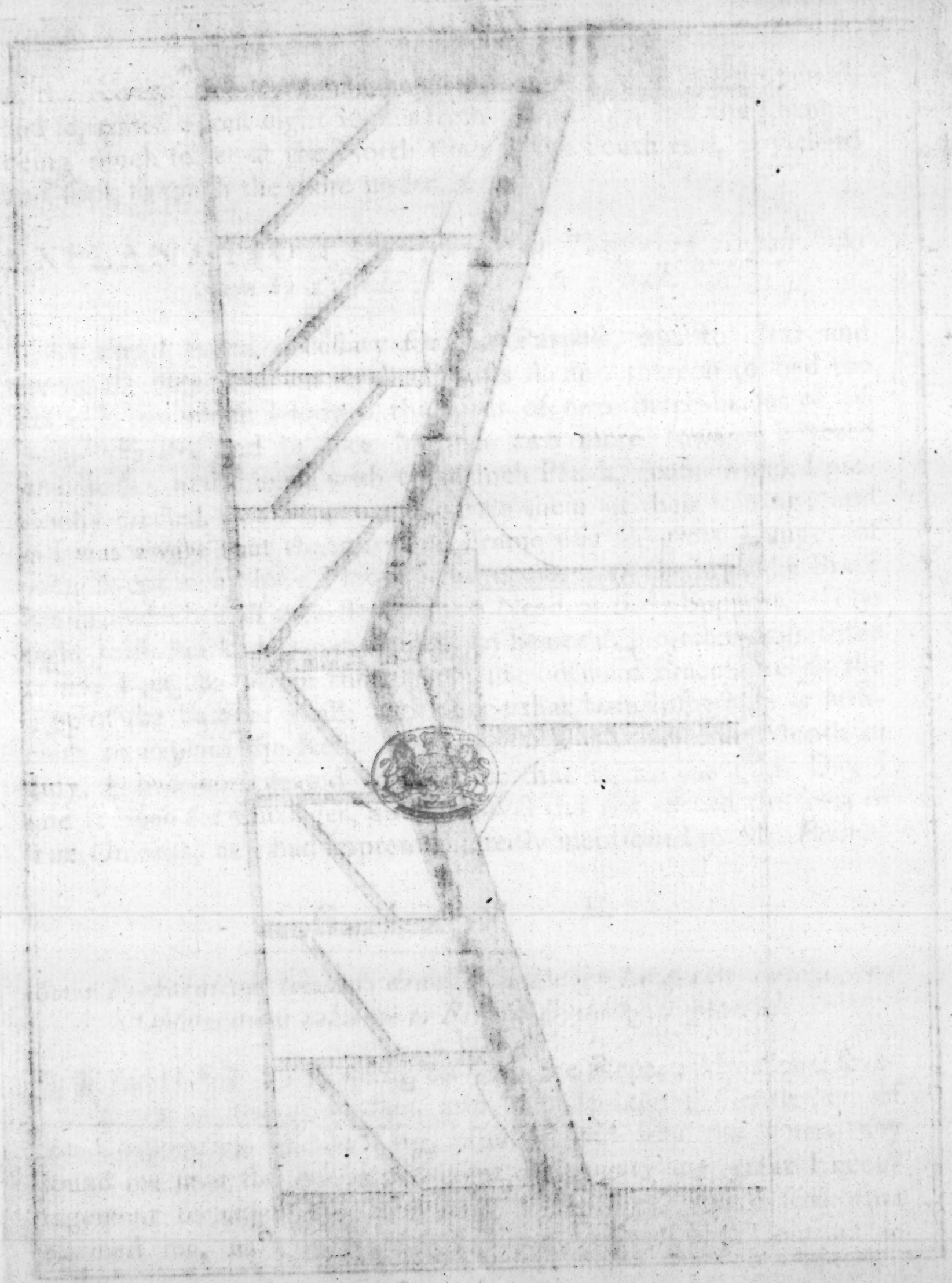
CHAP. II.

Some Preparatives towards drawing a Deſign for a new Bridge, and Obſervations relative to Bridge-Building in general.

WHILST I was going on with the Repair, Mr. *Prior*, ſeveral of the Aldermen, and other principal Gentlemen of the Corporation of the City, often viſited me, and when they found me near the Accompliſhment of it, gave me great Encouragement to engage in rebuilding the Bridge, which ſomewhat alarmed me, as I was at that Time engaged by Contract in building

Pl. 3.





building St. *Patrick's* Hoſpital, two Houſes for the Rev. Dr. *Leigh* in *Capel-ſtreet*, and one for *Arthur Newburgh*, Eſq; I was alſo engaged in the conduct of the building a new Houſe for his Grace the Lord Archbiſhop of *Dublin*, and another for Colonel *Ram*, at *Gorey*, &c. However, I found myſelf extremely inclined to engage in the building the Bridge, though I well knew it would be a very arduous Taſk.

I had on many Occaſions before felt a great Deſire to acquire Knowlege in difficult Matters of Arts and Science; and whenever they grew eaſy and familiar to me, I could no longer perceive in them the Charms which had before captivated me. Intereſt alone could never ſway me in theſe Reſearches and Purſuits; but from my earlieſt Days I had entertained a Notion, that the greater the Difficulty, the ſweeter the Conqueſt. In ſhort, that Subject took firm Poſſeſſion of me; and I applied myſelf to ſearch my Books, of which I then had a fine and valuable Collection, and I found in them numerous elegant Deſigns; but as touching the laying a Foundation in deep and rapid Rivers, all the Authors were in a Manner ſilent.

This Deficiency in ſo many excellent Authors, greatly amazed me; and in Hopes of procuring better Inſtructions, I ſettled my domeſtic Affairs, and went to *London*, where I procured about 40*l.* worth of Books, Plans, *&c.* which I ordered to be ſent after me, and returned Home within the compaſs of fourteen Days, full of Hopes that by their Aſſiſtance, I ſhould be able to pick out ſomething for my Purpoſe; but after I had attentively peruſed them, I found myſelf in the ſame Situation I had been in before.

I cannot deſcribe the Indignation and Sorrow I felt, at finding an Art of ſuch public Utility, as that of building Bridges confeſſedly is, ſo ſhamefully neglected: However, theſe Books furniſhed me with many uſeful Hints, and Obſervations, ſome few of which, I ſhall give for the Improvement of the young Student, and as neceſſarily connected with the Subject I am treating.

SECT.

SECTION I.

Hiſtorical Accounts of ſome remarkable Stone Bridges in foreign Parts.

IT has been a Rule laid down by the Writers on Science in general, that Excellence in any particular Branch is only to be acquired, by attentively and diligently peruſing and digeſting the Works and Deſigns of the moſt eminent Authors and Artiſts; but the young Student ſhould always be on his Guard, when he is about deſigning any Thing, that a too lively or over-heated Imagination does not lead him into Chimeras, which ſober Judgment would not approve. This Error may be in a great Meaſure avoided, by paying a proper Deference to the Sentiments of learned Men. For my Part, I think a young Man will gain greater Reputation by being an humble Copier of an ingenious Artiſt, than to pretend to excel every one by the Fertility of his own Imagination. But in ſuch Matters, where you cannot be furniſhed with Precedents, you are under a Neceſſity of ſtriking out ſomething from your own Brain. Yet theſe are not to be abortive, miſhapen Beings, the mere Creatures of a wild Fancy, but the fair, the legitimate Offspring of a well-regulated Judgment. This Obſervation deſerves to be well attended to in all Caſes; but particularly in thoſe where a Miſcarriage may be attended with fatal Conſequences.

There are an infinite Number of Bridges over the natural and artificial Rivers in *China*. We ſhall content ourſelves with obſerving one of the moſt famed, which is the Stone Bridge over the River *Saffrany*, which joins two Mountains together, and is in one ſingle Arch, which ſpans 600 Feet. From its Foundation to the top of the Parapets is 750 Feet, and from the exceeding great Height of it, Travellers have given it the Name of the *flying Bridge*. There is another very remarkable Stone Bridge at *Oxu*, the Capital of *Fo-kin*, which conſiſts of 100 Arches. But as we have a long Journey before us, we cannot make any further Remarks on the Bridges in *China*, and therefore, we muſt make large Strides, and ſtep over to the *Danube*.

The

The next enormous Bridge I ſhall mention, is that which the Emperor *Trajan* had built over the *Danube*, in order to convey his Troops with the greater Readineſs to fall on the Barbarians; but I find a great Diſagreement among the Hiſtorians concerning it.

Some ſay, this Bridge was one of the moſt amazing Works in the World; but they generally agree, that it was compoſed of twenty Arches, nineteen Piers, and two Land Abutments, all of ſolid Maſonry; each Arch was 170 Feet Span. The Piers, we are told, were 60 Feet broad, and 150 Feet high; that each of the Land Abutments was 120 Feet (which is twice the Thickneſs of the Piers) that the Arches were all true Semi-circles, and that it was built where the River was narroweſt, and conſequently the moſt rapid, which renders the Fabric ſtill more ſtupendous and amazing, on Account of the prodigious Difficulties they muſt have met with in laying the Foundations. But ſome relate that the ten outward Piers were built on an artificial Foundation, made by wheeling in vaſt Quantities of large and ſmall Stones, and other filling, after the uſual Manner of carrying a Mole into the Sea, but they form not the leaſt Conjecture, how the Piers were erected in the middle of the River.

The Architect employed on this Occaſion was one *Apollodorus* of *Damaſcus*, who it ſeems, left a Deſcription of this great Work, which (the Hiſtorian ſays) may be ſeen in *Procop. de Ædificiis*, *Juſtin*, B IV. c. 6. But when *Adrian* came to be Emperor, he ordered the Arches to be demoliſhed, to prevent the Barbarians making Excurſions into his Territories. But *Dion Caſſius* relates, that the Piers were ſtanding in his Time, which was 120 Years after the Bridge was built; but when it was entirely demoliſhed, the River was ſo choaked up with the Ruins, that it was not navigable, which obliged them to make a new Channel for it. We ſhall treat of this no further at preſent, but proceed in more uſeful Enquiries, and ſee what ſome of the moſt eminent Architects have left us concerning Stone Bridges.

SECT.

SECT. II.

A ſhort Abſtract from LEON BATTISTA ALBERTI.

THIS Author in his 8th Book, Chap. 6. Page 62. ſays, the Parts of the Bridge are the Piers, the Arches and the Pavement, or the Street in the Middle for the Paſſage of Cattle, and the raiſed Cauſey on each Side for the better Sort of Citizens, and the Sides or Rails, and in ſome Places Houſes too, as in that moſt noble Bridge, called *Adrian's Mole*, a Work never to be forgotten; the very Skeleton whereof (if I may ſo call it) I can never behold without a Sort of Reverence and Awe. It was covered with a Roof ſupported by two and forty Columns of Marble, with their Architraves, Freeze and Cornice, the Roof plated with Braſs and richly adorned.

A Bridge muſt be made as broad as the Street which leads to it. The Piers muſt be equal to one another both in Number and Size, and be one third of the Aperture in Thickneſs. The Angles, or Heads of the Piers, that lie againſt the Stream, muſt project in Length half the Breadth of the Bridge, and be built higher than the Water ever riſes. The Heads of the Piers that lie along with the Stream muſt have the ſame Projection; but then it will not look amiſs to have them leſs acute, and as it were blunted. From the Heads of the Piers on both Sides, it will be very proper to raiſe Buttreſſes for the Support of the Bridge, in Thickneſs, not leſs than two thirds of the Pier itſelf. The Crowns of all the Arches muſt ſtand quite clear above the Water. Their Dreſs may be taken from the Ionick, or rather the Dorick Architrave; and in large Bridges, it muſt not be leſs in Breadth than the fifteenth Part of the whole Aperture of the Arch.

To make the Rails, or ſide Walls of the Bridge the ſtronger, erect Pedeſtals at certain Diſtances by the Square and Plumb-lines, on which, if you pleaſe, you may raiſe Columns to ſupport the Roof or Portico. The height of this ſide Wall with the Zocle and Cornice muſt be four Feet. The Space between the Pedeſtals may

be

be filled up with a ſlight Breaſt-work. The Crown both of the Pedeſtals and Breaſt-wall, may be an upright *Cymatium*, or rather a reverſed one, continued the whole length of the Bridge, and the Plinth at the Bottom muſt anſwer this *Cymatium*.

The Cauſey on each Side for Women and Foot-paſſengers, muſt be raiſed a Foot or two higher than the Middle of the Bridge, which is intended chiefly for Beaſts and Carriages, and may be paved with Flints. The Height of the Columns, with their Entablature, muſt be equal to the Breadth of the Bridge.---And he has given us the Draft of a very neat little Bridge of three ſmall Semi-circular Arches, with a Roof ſupported by thirty Ionick Columns, *&c.*

In the 6th Chapter of his fourth Book he treats of Wooden Bridges, which is foreign to our Purpoſe; but I cannot omit ſome Things he has therein obſerved concerning Stone Bridges.------- "Make," ſays he, in Page 72, "the Foundations of your Piers in Autumn, when the Water is loweſt, having firſt raiſed an Incloſure to keep off the Water, which you may do in this Manner: Drive in a double row of Stakes very cloſe and thick ſet, with their Heads above the top of the Water like a Trench, then put Hurdles within this double Row of Stakes, cloſe to that Side of the Row which is next to the intended Pier, and fill up the Hollow between the two Rows with Ruſhes and Mud, ramming them together ſo hard that no Water can poſſibly get through; then whatever you find within this Incloſure, Water, Mud, Sand and whatever elſe that is a Hindrance to you, throw them out, and dig till you come to a ſolid Foundation; or if you find it neceſſary, make one of Piles burnt at the Ends, and driven in as cloſe together as ever they can ſtick. And here I have obſerved that the beſt Architects uſed to make a continued Foundation of the whole length of the Bridge, and not only under each Pier; and this they did, not by ſhutting out the whole River at once by one ſingle Incloſure, but by firſt making one Part, then another, and ſo joining the whole together by Degrees; for it would be impoſſible to withſtand and repulſe the whole Force of the Water at once: We muſt, therefore, whilſt we are at Work at one Part,

leave another Part open for a Paſſage for the Stream. You may leave theſe Paſſages either in the Channel itſelf, or if you think it more convenient, you may frame Wooden Dams or hanging Channels, by which the ſuperfluous Water may run off; but if you find the Expence of a continued Foundation for the whole Bridge too great, you may only make a ſeparate Foundation for every particular Pier, in the form of a Ship, with one Angle in the Stern, and another in the Head, lying directly even with the current of the Water, that the force of the Water may be broken by the Angle. We are to remember, that the Water is much more dangerous to the Stern, than to the Head of the Pier," *&c.*

SECT. III.

Extract from the celebrated ANDREA PALLADIO.

IN his third Book, Chap. 4. Page 138. He lays down the following Rules, and ſays, --- " Bridges ought to have the ſelf-ſame Qualifications that we judge neceſſary in all other Buildings, which are, that they ſhould be commodious, beautiful and laſting; they will be commodious, when they will not be raiſed above the level of the reſt of the Way, or if they are, when they are of eaſy Aſcent and Deſcent; and likewiſe, when ſuch a Place is choſen for building them, as ſhall be moſt convenient for the whole Province or City.---Bridges will be fine and laſting, if they are made after the Manner and according to the Proportions ſpecified in this Book; but in the Choice of a Situation for erecting them, Care muſt be taken to fix on ſuch a Place as may give good grounds to expect that the Bridge may be perpetual, and where it may be erected with the leaſt Expence. That Place muſt be choſen where the River is narroweſt, and alſo the moſt ſhallow, and where its Bed or Bottom is even and uniform, and is either of Stone or of Gravel, becauſe Stone or Gravel are excellent Foundations in Water. Moreover, Swallows or Whirlpools, and that Part of the River's Bed which is ſandy, or has much ſoft Clay in it, ought to be avoided;---but in Caſe the Bed of the River be altogether Gravel or Sand, then the Foundations

Foundations muſt be made according to the Directions I ſhall lay down hereafter."

Chapter X. Page 153.--"In Bridges of Stone four Things are principally to be conſidered, *viz.* The Heads which are made at the Banks; the Piles or Pilaſters, which are fixed in the River; the Arches which theſe Pilaſters ſupport, and the Pavement which is made over the Arches.

The Heads of theſe Bridges ſhould be made as firm and ſubſtantial as poſſible; becauſe, they not only ſerve to ſupport the Weight of the Arches as other Pilaſters do, but they likewiſe keep the whole Bridge together, and the Arches from cracking or opening: They ought, therefore, to be made where the Banks are the moſt ſolid.---The Pilaſters, which are to be made in Proportion to the Largeneſs of the River, ſhould always be even with regard to their Number.---The Foundations of Bridges ought to be made in Autumn, and in Caſe the Bed of the River be Stone or Gravel-Stone, you have the Foundation without any trouble; but in Caſe the Bottom be Quick-ſand or Gravel, you muſt dig therein till you come to ſolid Ground; or if that ſhould prove too laborious or impracticable, you muſt dig moderately deep in the Sand or Gravel, and then you muſt thruſt in Oak Piles, which will reach the ſolid or firm Ground, with the Iron by which their Points are to be armed.

To lay the Foundations of the Pilaſters, only one Part of the Bed of the River muſt be encloſed from the Water, and then to build there; that the other Part being left open, the Water may have its free Current, and ſo go on from Part to Part.

The Pilaſters muſt not be leſs in Dimenſions than the ſixth Part of the Breadth of the Arch, nor generally ſpeaking larger than the fourth; they ſhould be made of great Stones, which are to be joined together with Cramps and Bars of Iron faſtened with Lead, that they may be all as it were of one Piece; the Fronts of the Pilaſters, or that Side which faces the Stream, are ordinarily made Angular, i. e. that they end in a right Angle, and ſometimes they are made Semi-circular in order to divide or break the Water, and that thoſe Things which are impetuouſly brought down the River

when they ſtrike againſt them, may be ſhoved from the Pilaſters and paſs through the middle of the Arch.

The Arches too ſhould be made very ſtrong and ſubſtantial, and with great Stones well united together, the better to reſiſt the conſtant paſſing of Carriages, or any other Weight that may happen to come over them. Thoſe Arches are the ſtrongeſt that conſiſt of a Semi-circle, becauſe they intirely reſt upon the Pilaſters and never preſs upon each other; but if by Nature of the Situation and Diſpoſition of the Pilaſters, a perfect Semi-circle ſhould not be commodious, as rendering the Aſcent and Deſcent difficult, a leſſer Section muſt then be made uſe of, and ſuch Arches made as riſe only the third Part of the Diameter, and in this Caſe, the Foundation muſt be made extremely ſtrong upon the Banks, *&c.*

In his XIth Chapter, Page 155, he begins to treat of particular Bridges, and ſays, " Abundance of Bridges were erected by the Antients in ſeveral Places, but particularly in *Italy*, and on the *Tyber*, whereof ſome are at this Day intire, and others have ſome ſmall Remains only left to preſerve their Memory."---And in Page 156, he ſays, " Extraordinary great and moſt deſerving of Admiration, was that Bridge built over the *Danube* in *Tranſilvania*, and on which were inſcribed theſe Words, " *Providentia* Auguſti, *vere Pontificis*, *virtus* Romana *quid non Domet? Subjugor ecce rapidus Danubius*," i. e. " This is a memorable Monument of the Labour and Aſſiduity of *Auguſtus*, the *Roman* Pontiff: What will not *Roman* Valour enterpriſe ?"

But of all the Bridges that I have mentioned, that appears to me to be the moſt beautiful and the moſt worthy of Obſervation (not only for its Strength but the Compartment of it) which was erected at *Ariminum*, a City of the *Flaminian* Tribe, and I believe by *Auguſtus Cæſar*. It is divided into five Arches, the three middlemoſt whereof are equal, conſiſting of 25 Feet in Breadth, and the two next the Banks are leſs, conſiſting only of 20 Feet; all theſe Arches conſiſt of a Semi-circle, and the Depth of their Archivolte is a tenth Part of the light or void of the greater, and an eighth Part of the light of the leſſer ones. The Pilaſters, as to their Thickneſs, are a little more than the half of the light of the greater Arches;

Arches; the Angle of the Spurs, which cut the Water is a right Angle. This, as I obſerved, the Antients followed in building all their Bridges, as being ſtronger than the acute Angle, and for that Reaſon, the obtuſe Angle is leſs expoſed to be thrown down and deſtroyed by Trees or any other Matter, that rolls down with the Stream. On the Sides of this Bridge, there are four Ionic Niches, with pitched Pediments over the four Pilaſters; there is a Cornice over theſe Niches, the Length of the whole Bridge = 1 $\frac{3}{4}$ Foot high, conſiſting of a Semirect and a Semirevers and *Tuſcan* Blocks. The Piers are ſunk 7 Feet into the Bed of the River, the Water is ſix Feet deep, and the Arches ſpring 6 Feet above the Surface of the Water.

His XIIth Chap. P. 158, is concerning the Bridge of *Vicenza:* " Two Rivers run through *Vicenza*, one whereof is called the *Bacchiglione*, and the other the *Rerone:* This laſt enters into the firſt, juſt without the City, and ſo loſes its Name immediately. There are two antient Bridges built over theſe Rivers, one of which is demoliſhed; the other is divided into three Arches, the middlemoſt is 33 Feet broad, the other two are 22 $\frac{1}{2}$ Feet each. The Pilaſters are the 5th Part of the leſſer Arches, and the 6th of the greater, and the Arches riſe $\frac{1}{3}$ of their Diameter; their Archivolte has $\frac{1}{9}$ of the ſmall, and $\frac{1}{12}$ of the large Arches, which is a common three-faced Architrave; the Piers have a Plinth that projects about a Foot, and a Foot under the ſpringing for the ſupport of the Centres, and from the level of that Courſe the front of each Pier is hip'd of, and from hence the Architraves ſpring. The Bridge is 24 Feet from out to out."

Chap. XIV. P. 161. deſcribes a Bridge, of his own Invention. " The River is 180 Feet. In three Arches, the middle Arch 60 Feet, and the ſide Arches 48 Feet each; the Pilaſters 12 Feet thick, and the Points of the Cutwaters (which are a right Angle) extend 12 Feet each beyond the naked of the Bridge; the middle Arch riſes 20 Feet, the ſide ones 16 Feet, with a three-faced Architrave the 17th of the middle, and the 14th of the ſide Arches. The Piers finiſh at the Spring with two leaning Figures,

over

over which there are two Corinthian Niches with Statues and pitched Pediments. This Bridge is 30 Feet from out to out."

SECT. IV.

A ſhort Abſtract from SCAMMOZZI *and* SEBASTIAN SERLIO.

SCAMMOZZI has alſo treated of Stone-bridges, and the laying their Foundations; for which Purpoſe, he generally approves of piling, as the ſafeſt Way where the Ground is ſoft. He ſays, he laid two Deſigns before the Senate of *Venice*, for the *Pont Rialto*, one of three Arches, and the other of one Arch, which he propoſed to lay over the great Canal, with Piles of Timber drove into the Ground, then with Net-work of Timber upon them, and Planks of Oak upon the Net-work, on which the Stone-work was to be raiſed; and there is not the leaſt doubt but he drew and propoſed to execute this Plan of the one Arch, but it is generally allowed as the Work of *Michael Angelo*, built by him in 1591. Indeed, it is a moſt noble Arch; I have now three ſeparate Drawings of it by me, but they had not any Difficulties of Water to encounter with. The Arch is the Segment of a Circle, the Span 98½ Feet. It ſprings at high Water Mark, and riſes 23 Feet, *&c.* But let us come more to our Purpoſe.

Scammozzi propoſes four different Methods to lay Foundations in deep Water, *viz.*

1ſt. To ſhut up the River in Parts on one Side, and then on the other, by driving a double Row of Piles, and filling in between them with good Chalk, or ſome cloſe Materials, then to pump out the Water from the incloſed Part, and clear out the Mud; after that, to pile the Foundation to the extent of the intended Pier, and then to begin your Foundation of Stone, upon a Platform of Plank.

2d. Having ſounded the Water, and levelled the Bed of the River, to prepare a Grillage of Oak, ſtrong and well pinned, and bound faſt together with Iron, and kept upon the Surface of the Water by large Hulks or Gabbards, with Cables and other Machines,

chines, having a thick Stratum of large Stones laid on this Frame of Timber, the Stones being well cramped together, and the Joints filled with ſtrong Puzzoli, Terraſs, or Cement, and then letting them down gently to the Bed of the River by proper Machines and Cables.

3d. To turn off the River another Way, or to make ſeveral Channels to ſink the Water, then with a Number of Workmen to make a Dam with Piles, above and below where the Bridge is to ſtand, quite a-croſs the River, and ſo turn the Stream into the new Channel; then to clear the Earth and Mud away, where the Foundation of the Bridge muſt be laid, and to build the Piers above the Water, and after that to let the River return into its proper Channel.

4th. He ſeems to think that the Emperor *Trajan* muſt needs have made uſe of the following Method, in building that wonderful Bridge over the *Danube*, *viz.* To take an Elbow or Bend of the River where it makes a Peninſula, to cut out a direct Canal through the Neck of Ground or Iſthmus, then to build the Bridge with eaſe and upon dry Ground, and afterwards to open the Paſſage through the Ground left at each end of this new Bed or Channel, whilſt the Bridge is building, then turn the River through it, making ſtrong Dams on the old Channel to divert the River from its former Courſe.

Sebaſtian Serlio mentions the Proportions of ſome of the principal Bridges at *Rome*, &c. which I think, we do not now ſtand in any need of, as our chief Enquiry is after the ſureſt and moſt practicable Method, of laying a Foundation of about ſeven and twenty Feet under High-water, in an exceeding rough and rapid River; and as I am certain there is not one of all theſe which we now have before us, that will anſwer our Purpoſe, let us turn our Faces Homewards, and on our Way take a curſory View of ſome of the Bridges in *France*, and let us reſolve to inſpect narrowly into the Methods, which we hear, they have practiſed with great Succeſs, in laying the Foundations of many of their Bridges.

SECT.

SECT. V.

Brief Accounts of ſome of the Stone Bridges in France, *and their Methods of building them.*

THERE are many magnificent Bridges in *France*, both antient and modern, and we ſhall begin with the *Pont Royal* at *Paris*, which was built in 1685, by Monſ. *Manſart:* This Bridge is built over the *Seine*, oppoſite to the Grand Pavilion of the *Thuilleries*, and was executed according to the Plan ordered by the King. The River in this Place is about 403 Feet Engliſh, and the Bridge conſiſts of 4 Piers and 5 Arches; the middle Arch is 77 Feet, the two next 74 Feet each, and the two next the Quays 58 Feet each; the two middle Piers are each 16, and the two other Piers 15 Feet each; the middle Arch is 26 Feet high from the ſpringing, and is elliptical, and ſo are the reſt in Proportion; the Road over it is divided into three Parts, the middle is 32 Feet 6 Inches, and the Foot-ways on each Side are 9 Feet 9 Inches broad, and ſeparated by Stone-poſts; the Parapets are 2 Feet thick, and 3 Feet 3 Inches high; the River in this Place is about 7 Feet deep, and the Bridge was erected by Means of Batterdeaux.

The Bridge at *Blois*, was deſigned by the Sieur *Gabriel:* Breadth of the River 935 Feet Engliſh; it has 10 Piers, 2 Abutments and 11 elliptical Arches; the middle Arch is 86 Feet 9 Inches, the two next 80 Feet each, the two next 73 Feet each, the two next 66 Feet each, the two next 60 Feet each, and the two next to the Quays are 55 Feet 4 Inches each: Total Water-way 755 Feet 5 Inches; the two middle Piers are 22 Feet 6 Inches each, the two next are 17 Feet 2 Inches each, and the other ſix are 16 Feet 1 Inch each: Total ſolids = 175 Feet 10 Inches, and the two Abutments = 60 Feet; the Piers project 16 Feet beyond the extent of the Bridge on the upper Side, and 10 Feet below the Bridge, and terminate in right Angles; the Height of the middle Arch is 30 Feet 10 Inches, and the reſt in Proportion, and all elliptical;

from

From the bottom of the Piers to the ſpring of the Arches it is 16 Feet 6 Inches; the Breadth of the Bridge is 45 Feet 6 Inches, between the Parapets, which are 2 Feet 2 Inches each; the Carriage-way is 30 Feet, and each of the Foot-ways is 7 Feet 7 Inches, and raiſed about a Foot above the Carriage-way; the Foundations were laid on Oak Piles, and the Water kept off in the mean Time by Batterdeaux.

There are a vaſt Number of other very excellent Bridges in *France*, whoſe Foundations have been laid after the ſame Methods, on which I ſhall make ſome Remarks very ſoon; but as I am not writing a Hiſtory of Bridges, I ſhall deſiſt; my preſent Purpoſe being to find out and lay down ſome effectual Methods to keep off the Water till we ſhould accompliſh our Deſigns, which I ſhall now begin to prepare for and to conſider minutely, not by Way of Precedent, but in order to ſhew young Students that there are an infinite Number of Matters and Things to be thoroughly examined and digeſted, before one can ſit down to draw a proper Deſign of this Nature; for in many Caſes, a Plan or Deſign, that may appear curious or elegant enough upon Paper, may prove the Inſtrument of involving both the Projector, his Employers and the Public in very diſagreeable Circumſtances, of which there are numerous flagrant Inſtances to be met with.---But to proceed.

CHAP. III.

A ſuccinct Narrative concerning the re-building of Eſſex-bridge.

SECT. I.

On the Plan, Soundings and Borings of the former Bridge.

EXPLANATION *of* PLATE IV. *Scale* 30 *Feet* 1 *Inch.*

THIS Plate exhibits a Plan of *Eſſex-bridge*, as it was in 1751, and the Baſs of the Effigy, with ſome of the Borings or Piercings into the Bed of the River, as alſo the Soundings above

and below it: In explaining of which, I ſhall demonſtrate the Cauſe of the Failure thereof, wherein note,

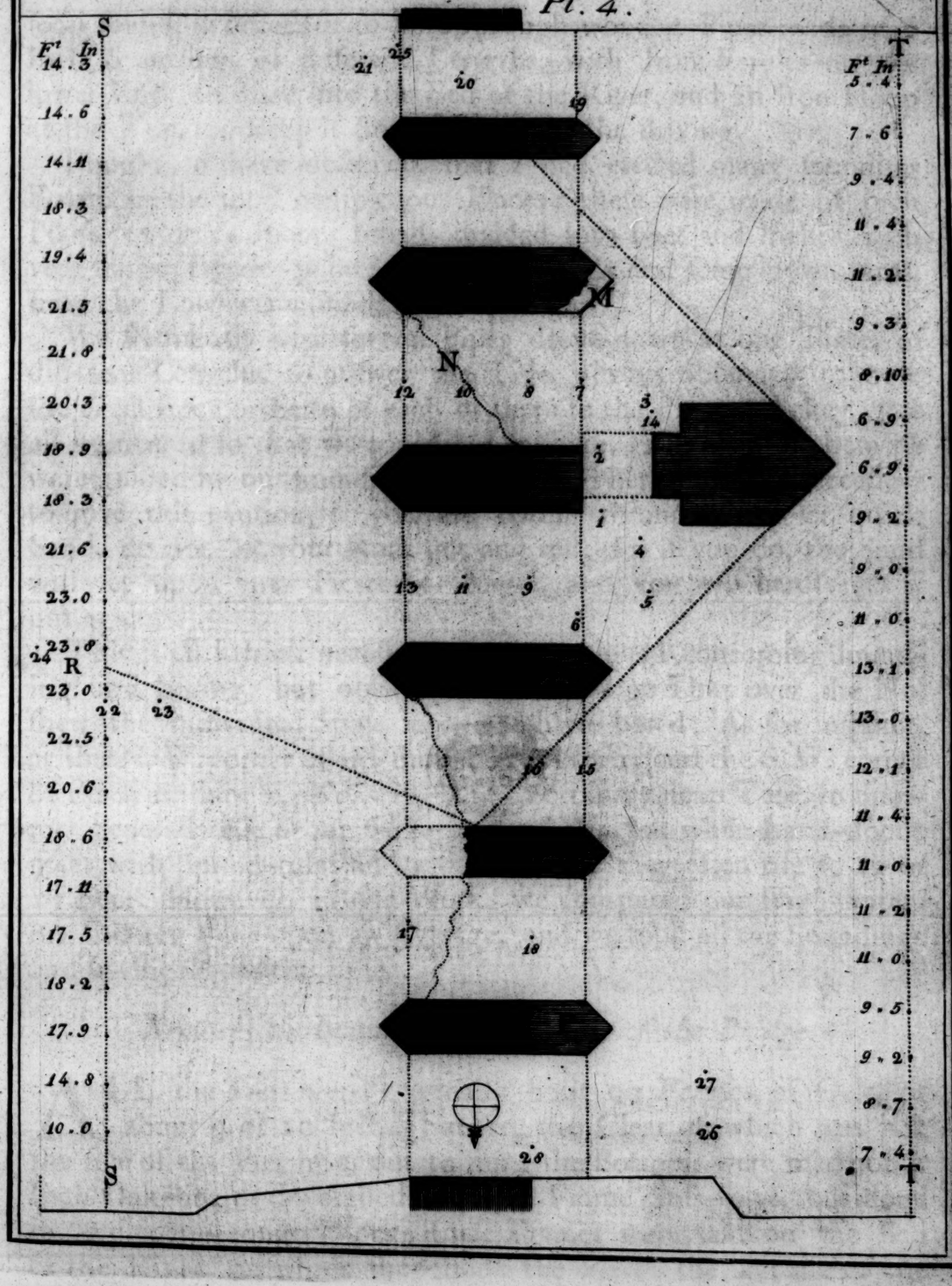
L. The Pier that was rebuilt, and now ſtanding on the Ruins of a former Arch, as before-mentioned. M. Part of the Under-work of the ſecond Pier of the Foot-way, failed and carried off by the Floods. N. Shews a Diagonal opening quite acroſs the third Arch, cauſed by the ſecond Pier having ſunk into the Bed of the River Weſtward, and the third Pier Eaſtward. O. What now remains of the fifth Pier. P P. The two Piers of the Foot-way that have ſunk the moſt into the Bed of the River. Q. Baſs of the Effigy. R. Shews how the Current is now directed by the Baſs of the Effigy, the Conſequence of which ſhall be hereafter explained. S S. Shews the Soundings of the River at High-water, taken in a direct Line, 60 Feet below the Bridge, in every 10 Feet. T T. Shews the Soundings of the River in every 10 Feet, taken in a direct Line, 65 Feet above the Bridge.

I took theſe Soundings in the following Manner: I had a Hawſer ſtrained very tight from Quay to Quay, to which we moored our Boat, and over that at a proper Height, we had a tight Rope marked in 10 Feet Diviſions, and numbered. I had alſo a ſounding Rod, made of a Piece of Scantling 26 Feet long, 4 by 2 at the lower End, and $2\frac{1}{2}$ by $1\frac{1}{2}$ Inches at top; the Butt of it was firmly fixed in a Cut-ſtone of 4 Inches thick, and about 20 Inches Diameter. The Rod was marked out in Feet and Inches painted. In the Butt of the Rod there was a Hole, through which a long Piece of Saſh-cord was drawn, by which we hove the Rod along, noting the Depth at every Diviſion, and notwithſtanding the Rapidity of the Water, we got this done with tolerable Exactneſs.

I took the following Method to bore the Bed of the River; the Rods were in three Pieces of Inch Square Bar of juſt nine Feet each, which ſcrewed together occaſionally; into the lower one the Chiſſell or Augers were ſcrewed, the Chiſſell or Piercer, was well ſteeled, with a drill Point; we had a handle like that of an Auger, which moved up or down, and by a Screw made tight whenever we pleaſed: Practice ſoon taught us, that we did not know how to perform this trifling Piece of Work in that rapid Water; but we

ſoon

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ſoon found it neceſſary to bore through wooden Pipes made of 6 Inch Scantling, of different Lengths, with Iron Ferules on the lower End, to drive into the Bed of the River, and an Iron Hoop at the Top, to keep it from ſplitting in the driving.

I ought to have obſerved, that I had erected many ſounding Boards in the moſt conſpicuous Places; theſe were made of Inch Plank 12 or 14 Inches broad, divided into Feet and Inches, with very large Figures painted, ſome upwards and ſome downwards, from the Low-water mark.

We frequently kept ſeveral Pipes drove down at one Time, of different Lengths, to anſwer the Tide, always obſerving to note the exact Spot or Scite of each of them in the Plan, and they were all numbered ſo that we could not miſtake, as in each of them we were guided by our ſounding Boards: And here I think it neceſſary to give this caution, if you are boring through ſharp or quick Sand, do not let your Rods get any reſt, for if you do, the Sand will ſet upon your Piercer or Augre, and you will hardly get it out again.

This is all I think neceſſary to be mentioned concerning ſounding and boring; but obſerve, that the large Dots over the No. ſhew the individual Spots into which we bored: As for inſtance, at the N. W. corner of the third Pier is No. 1, and the S. W. corner of the ſame No. 2, *&c.* N. B. The ordinary neap Tides in Summer generally riſe about 6 Feet and a half; but when Land-floods meet with Spring-tides and a S. E. Wind, they often riſe to 12 or 13 Feet: However, in our Work, we computed our High-water-mark at ten Feet upon an Average, and we took all the Soundings and Borings from the ſame.

Remarks on the cauſe of the Failure of the Bridge.

ALL the Piers were originally built on Frames of Oak, of about 9 or 10 Inches Square, the Clear of which was juſt the ſize of the Pier from out to out; the Bottoms were made of 2 Inch Oak-boards dovetailed into the Frame croſs-ways, but done in very coarſe rough Work; theſe Frames were laid on the Bed of the River, on which they built the Piers; the increaſe of the

Rapidity of the Water between the Piers, ſunk and carried off that Bed of the River left between the Piers, and continued to ſap and gull the Frames every Flood, and the Baſs of the Effigy Q. gave a new Direction to the Current, for that on the South Side was directed to the Pier L. where it was obſtructed by the Ruins of the former Arch, and as it hurried back to get into the third Arch, it ſapped the Foundation of the Foot-way, M. and on the North Side, the Strength of the Current was directed to O. where it did full Execution on that Pier, and then made its Way to R. where meeting again with the Currents that ran through the third and fourth Arches, they ſtruggled together, and ſo wore away the Bed of the River to 23 Feet 8 Inches deep, and ſometimes deeper, juſt as the Flood and Ebb happened to leave it. Now let us examine the borings of the Bed of the River.

BORINGS.

N°.	Feet.	Inches.	
1	11	9	To the Bed of the River.
	3	5	Pretty cloſe Gravel.
	3	6	Ditto. ſofter and finer.
	4	7	Ditto. rather cloſer.
	23	3	We came to the Rock.
2	11	6	To the Bed.
	11	6	Gravel and Sand.
	23	0	Rock.
3	9	6	To the Bed.
	6	0	Gravel and Sand pretty cloſe.
	6	6	Ditto. but cloſer and finer.
	22	0	Rock.
4	10	2	To the Bed.
	8	1	Gravel and Sand.
	5	9	Very ſharp Sand.
	24	0	Rock.

N°.	Feet.	Inches.	
5	10	2	To the Bed.
	8	10	Gravel and Sand.
	5	0	Very cloſe, ſharp Sand.
	24	0	Rock.
6	11	0	To the Bed.
	5	6	Coarſe, ſharp Sand
	6	6	Cloſe, ſharp Sand.
	23	0	Rock.
			Note, Between the 4th and 6th boring, by my giving a very ſhort reſpite to the Men, the Sand ſet on the Piercer, which we could not move afterwards, and we were obliged to unſcrew the upper Joint, and leave the Piercer and the lower Joint in the Ground.
7	10	9	To the Bed.
	7	9	Rough Gravel.
	3	6	Hard fine Sand.
	22	0	Rock.
8	10	9	To the Bed.
	7	9	Looſe rough Gravel.
	3	3	Cloſe and ſharp Sand.
	21	9	Rock.
9	13	0	To the Bed.
	4	0	Coarſe, looſe Sand.
	9	9	Cloſe and ſharp Sand.
	26	9	Rock.
10	12	0	To the Bed.
	7	0	Looſe, coarſe Sand.
	5	0	Cloſe, fine, ſharp Sand.
	24	0	Rock.
11	14	0	To the Bed.
	5	0	Looſe coarſe Sand.
	7	0	Looſe quick ſharp Sand.
	26	0	Rock.

N°.	Feet.	Inches.	
12	11	0	To the Bed.
	5	0	Coarſe, looſe Sand.
	5	0	Ditto. but finer.
	1	9	Rough and ſtubborn like Quarry Rubbiſh.
	22	9	Rock.
13	12	0	To the Bed.
	8	0	Looſe, quick and ſharp Sand.
	6	0	Rough and ſtubborn.
	26	0	Rock.
14	11	0	To the Bed.
	4	0	Looſe and ſtony.
	15	0	Here we were forced to deſiſt, it was ſo ſtony.
15	11	0	To the Bed.
	0	10	Very ſtony.
	6	0	Looſe, ſharp Sand.
	3	11	Cloſer ſharp Sand.
	3	6	Something finer ditto.
	0	6	Like Quarry Rubbiſh.
	25	9	Rock.
16	11	6	To the Bed.
	12	8	Sharp Sand.
	2	0	Something finer ditto.
	26	2	Rock.
17	11	0	To the Bed.
	3	0	Coarſe looſe Rubbiſh.
	8	0	Ditto. and gravelly Sand.
	5	0	Fine ſoft Sand, that we could almoſt thruſt down the
	0	9	Quarry Rubbiſh. [Rod into it.
	27	9	Rock.
18	10	0	To the Bed.
	7	0	Soft, looſe, gravelly Sand.
	1	0	Ditto. but much ſtiffer.
	7	0	Very ſoft looſe Sand, ſeemingly mixed with Mud, but not quite ſo ſoft as that of N°. 17.
	1	0	Like Quarry Rubbiſh.
	26	0	Rock.

N°. 19

N°.	Feet.	Inches.	
19	9	0	To the Bed. (South end)
	7	6	Coarſe Gravel.
	16	6	Rock.
20	9	3	Through the Rubbiſh.
	7	0	Very coarſe and ſtony ditto.
	16	3	Rock.
21	9	3	To the Bed.
	3	9	Stony Rubbiſh.
	3	2	Finer Rubbiſh or Gravel.
	16	2	Rock.
22	24	0	To the Bed. (near R.)
	1	7	Looſe Sand, or Mud.
	25	7	Rock.
23	24	6	To the Bed.
	1	3	Looſe Sand, or Mud.
	25	9	Rock.
24	24	9	To the Bed.
	0	11	Looſe Sand, or Mud.
	25	8	Rock. *N. B.* Theſe laſt three Numbers are taken in the deepeſt Part of the Whirl-pool, which nearly coroborate with the Soundings at R. which is 23 Feet 8 Inches deep.)
25	9	3	To the Bed. (South Arch)
	3	9	Rubbiſh or Ruins of the former Arch.
	3	3	Looſe Gravel.
	16	3	Rock.
26	7	6	To the Bed. (See North Side)
	8	0	Soft Sand.
	2	0	Ditto. but much ſtiffer.
	7	0	Ditto. ſtiffer and finer.
	1	6	Very ſtiff, and fine Sand or Loam.
	26	0	Rock.

N°.	Feet.	Inches.	
27	7	0	To the Bed.
	8	4	Looſe ſandy Loam.
	2	2	Ditto. but much ſtiffer.
	8	3	Ditto. ſtiffer and finer.
	25	9	Rock.
28	7	4	To the Bed.
	8	0	Soft Sand, or Loam.
	2	6	Ditto. but pretty ſtiff.
	7	0	Stiff Sand, or Loam.
	1	6	Ditto. and Quarry Rubbiſh.
	26	4	Rock.

SECT. II.

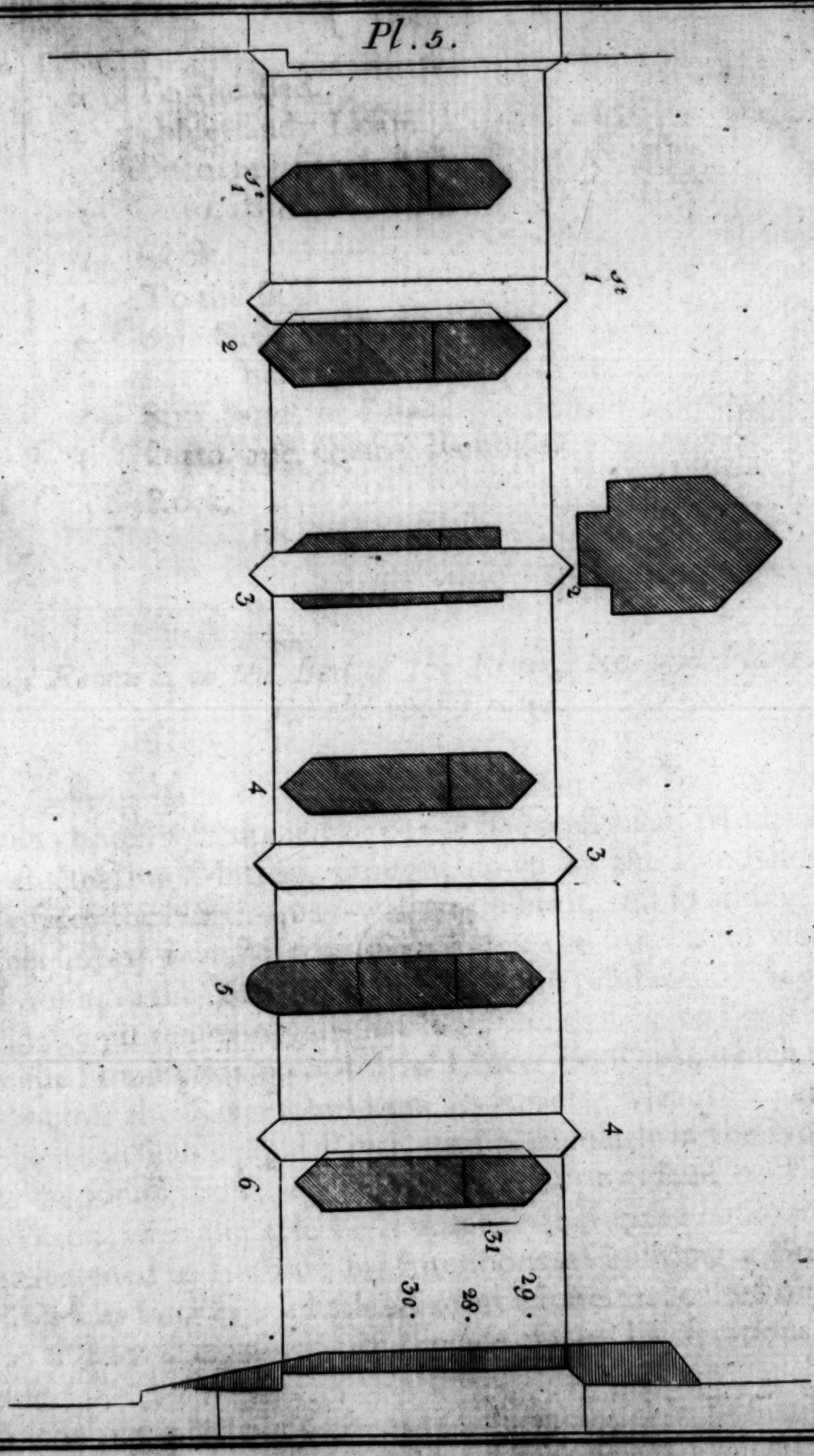
General Remarks on the Bed of the River, &c. *and Plans deſigned for the new Bridge.*

FROM theſe borings it appeared, that the Bed of the River was chiefly compoſed of coarſe Sand, Gravel, Mud, and other looſe fluctuating Matters, brought down by the Land-floods, but chiefly ſince the North-quay-walls were built, and ſo adding them all together in my own Mind, I found that the Sum total was, that I could not have the leaſt hopes of building a ſubſtantial Bridge in that Place, without removing all that looſe Subſtance, and getting down to lay the Foundation on or tolerably near the Rock, which we found quite a-croſs the River; but how, or by what Means to get that accompliſhed in ſuch a rapid River, and particularly in the North Side, where we found the Rock in ſome Places upwards of 27 Feet under high Water, was the ſole Circumſtance that quite confounded me, and threatened to fruſtrate my Intentions of building a Bridge that ſhould laſt as long as the little adjacent Mountain, called *Sugar-loaf-hill* as I had determined, and made ſome Declarations to that purpoſe.

To conquer all theſe ſeemingly inſurmountable Difficulties, engaged my whole Attention: Many Schemes and Projects crowded, and



Pl. 5.



and ſome of them made deep Impreſſions on my Imagination; but whenever the Apprehenſion of the Danger the Workmen would be in, in Caſe the Incloſure, I thought I had projected, burſt in upon them, they all vaniſhed.

In this diſtreſſed Situation I had frequent Recourſe to my Books, all of which could not afford me any ſort of Encouragement, ſaving what I have already laid before you: They told me, indeed, to make an Incloſure; and ſo might they tell a Man, that to meaſure Time, he muſt make a Clock; but what would that avail to a Man that had never made nor ſeen any kind of Machine for that purpoſe?---However, I proceeded to form my Plan of the Bridge, in projecting of which, I found myſelf moſt plentifully ſtored with Precedents, and yet after all (in Juſtice to Mr. *Labely*) I muſt declare that *Weſtminſter* Bridge deſerved the Preference; therefore (ſave only in ſome Particulars) I took it for my Precedent.

EXPLANATION *of* PLATE V. *Scale* 30 *Feet* 1 *Inch.*

THIS Plate repreſents the Plans of the Old-bridge, and the annexed Deſign of the New-bridge laid down together; not only to know the exact Parts of the Bed of the River as they then were, but as they were to be occupied by their reſpective Piers; and likewiſe to conſider and compare them together, with regard to their Voids and Solids.

OLD BRIDGE.

	Arches. Ft.	Arches. Inch.	Piers. Ft.	Piers. Inch.
1ſt or South Arch	18	5	0	0
1ſt or South Pier	0	0	8	10
2d Arch - -	18	5	0	0
2d Pier - -	0	0	12	11
3d Arch - -	27	9½	0	0
3d Pier - -	0	0	13	0
4th Arch - -	28	1	0	0
4th Pier - -	0	0	9	11
5th Arch - -	26	6	0	0
5th Pier - -	0	0	10	1
6th Arch - -	25	5	0	0
6th Pier - -	0	0	10	3
7th Arch - -	25	10½	0	0
Total =	170	6	65	0

NEW BRIDGE.

	Arches. Ft.	Arches. Inch.	Piers. Ft.	Piers. Inch.
1ſt or South Arch	36	0	0	0
1ſt or South Pier	0	0	8	0
2d Arch - -	41	0	0	0
2d Pier - -	0	0	9	0
3d Arch - -	46	0	0	0
3d Pier - -	0	0	9	0
4th Arch - -	41	0	0	0
4th Pier - -	0	0	8	0
5th Arch - -	36	0	0	0
Total =	200	0	34	0

By this Scheme it appears that the Water gains 29 Feet 6 Inches in Breadth, more than it had done in the old Bridge.

EXPLANATION *of* PLATE VI. *Scale* 30 *Feet* 1 *Inch.*

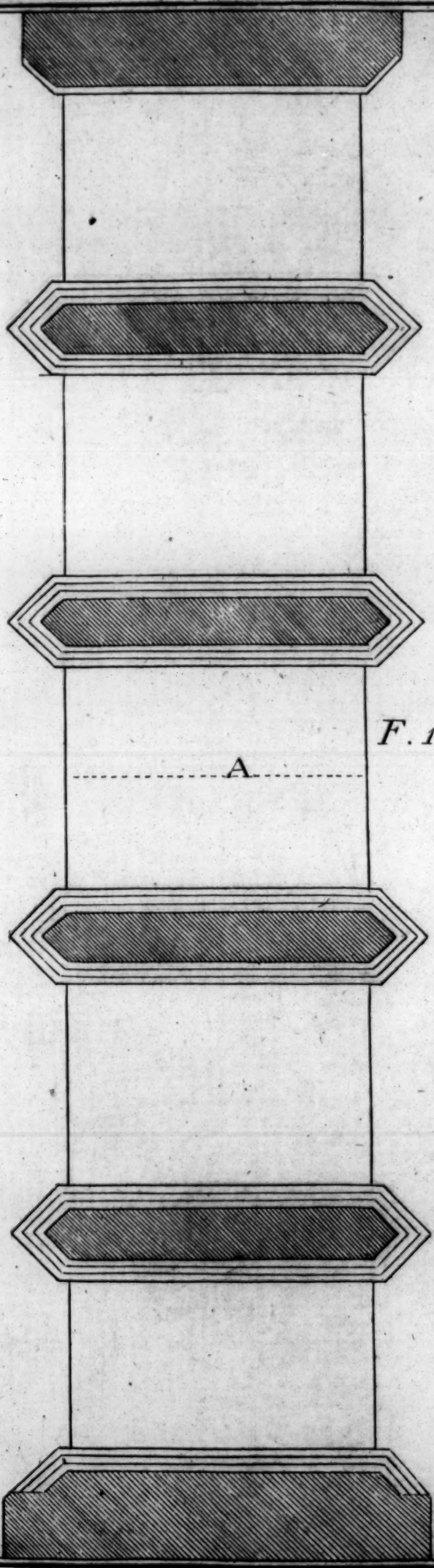
THIS Plate exhibits a Sketch Draft of the new Bridge, wherein note in Fig. 1, A. Breadth of the Body of the Bridge from out to out. In Fig. 2, B. the Rock. C. Surface of the thorough Foundation. D. Low-water Mark. E. High-water Mark. F. Pavement.

EXPLANATION *of* PLATE VII. *Scale* 40 *Feet* 1 *Inch.*

THIS Plate repreſents the firſt general Plan of Operation in laying the Foundations; wherein note, A. the Incloſure, or Coffer-dam. B. Pit for North end. C. Pool for the Pumps. D. Water Trunks.

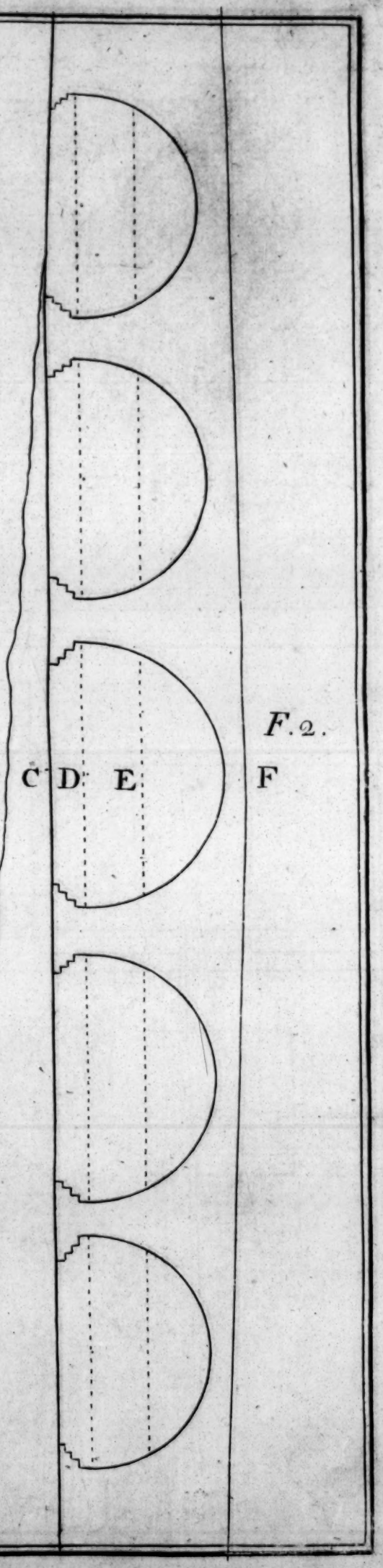
In

Pl. 6.



F. 1.

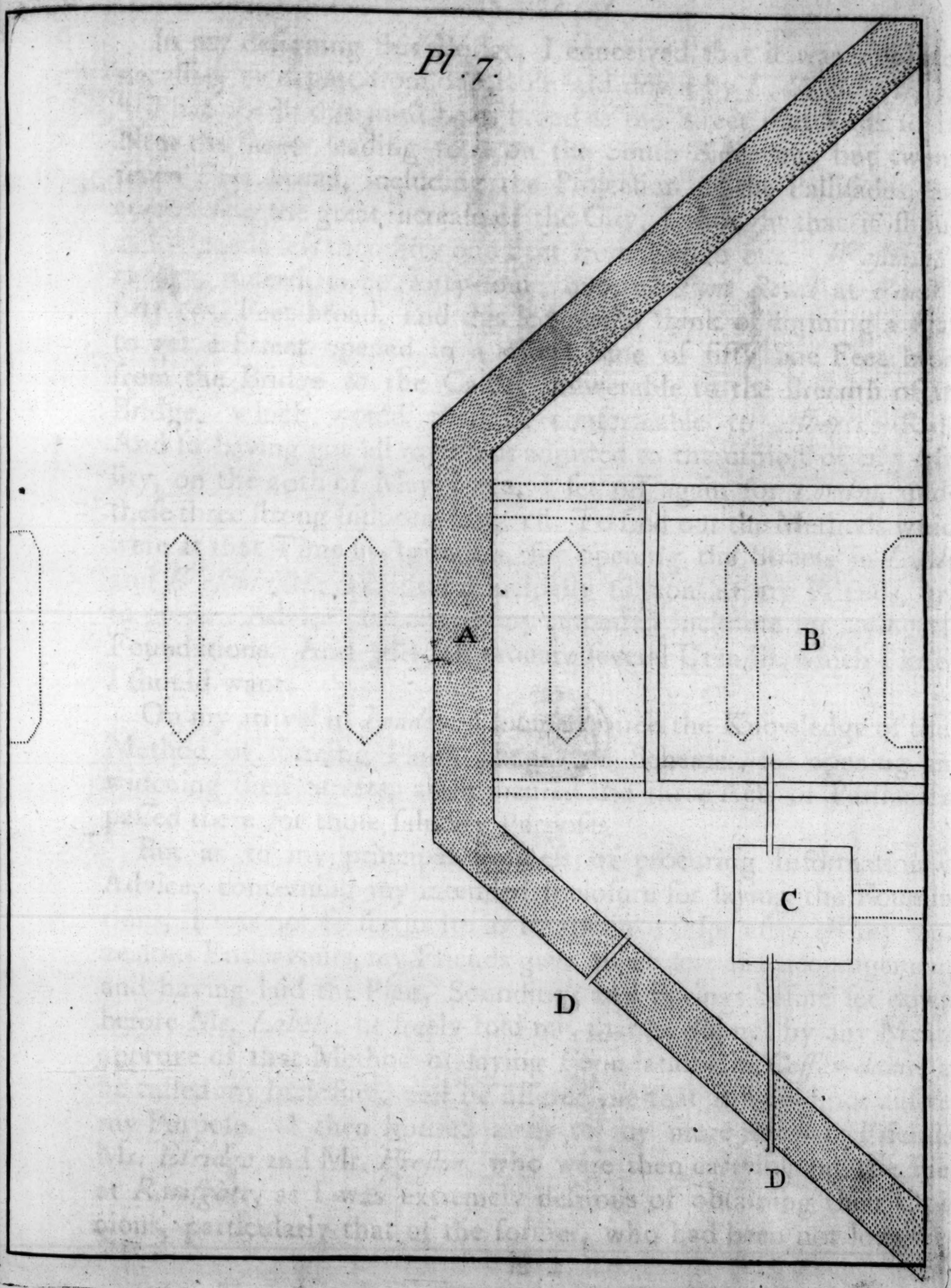
A



F. 2.

B C D E F

Pl. 7.



In my deſigning this Bridge, I conceived that it was abſolutely neceſſary to depart from one Rule laid down by *L. B. Alberti*, viz. " That the Bridge muſt be as broad as the Street that leads to it." Now the Street leading to it on the South Side, was but twenty ſeven Feet broad, including the Projection of the Palliſades, and conſidering the great increaſe of the City, I thought that it ſhould not be made leſs than fifty one Feet from out to out. *Weſtminſter* Bridge, indeed, is but forty-four; but the *Pont Royal* at *Paris* is fifty two Feet broad, and this led me to think of forming a Plan, to get a Street opened in a direct Line of fifty one Feet broad from the Bridge to the Caſtle, anſwerable to the Breadth of the Bridge, which would then be conformable to *Alberti*'s Rule: And ſo having got all my Plans adjuſted to the utmoſt of my Ability, on the 20th of May 1752, I ſet off again for *London*, under theſe three ſtrong Inducements, 1ſt. To find out the Methods which were at that Time in Agitation, for opening the Streets in *London* and *Weſtminſter*: 2d, And principally to conſult my Friends, and to procure Advice concerning my intended Incloſure for laying the Foundations. And 3dly, to procure ſeveral Utenſils, which I knew I ſhould want.

On my arrival in *London*, I ſoon acquired the Knowledge of their Method of forming Plans, Maps and Schemes, for opening and widening their Streets, and procured the three Acts of Parliament paſſed there for thoſe ſalutary Purpoſes.

But as to my principal Buſineſs of procuring Information or Advice, concerning my intended Incloſure for laying the Foundations, I was not ſo fortunate as to obtain it; for after all my moſt zealous Endeavours, my Friends gave me no ſort of Encouragement, and having laid the Plan, Soundings and Borings before ſet down, before Mr. *Labely*, he freely told me, that he did not by any Means approve of that Method of laying Foundations in *Coffer-dams*, as he called my Incloſure, and he aſſured me that it would not anſwer my Purpoſe. I then hurried away to my more intimate Friends, Mr. *Etridge* and Mr. *Preſton*, who were then carrying on the Pier at *Ramſgate*, as I was extremely deſirous of obtaining their Opinions, particularly that of the former, who had been not long be-

fore ſent over to project a Bridge for *Coleraine*, and at that Time was employed by ſome of the Gentlemen of the Corporation of the City, to view our ruinous Bridge, which he did. There was then only a little trifling Freſh in the River; he ſaw the Rapidity with which it fell; examined and informed himſelf about the Roughneſs of the Bed of the River, the Depth of the Water, *&c.* So I was ſure there was no other Gentleman in *England*, that could be ſo good a Judge of my Coffer-dams, as I ſhall now call my Encloſure. Theſe two Gentlemen were very courteous and communicative, and told me that as neither of them had ſeen that Method practiſed, they could not give me any ſort of Encouragement to attempt it; and the former concluded with theſe Words, 'take Care that you do not find yourſelf miſtaken;' and the latter, with this friendly and parting caution, 'above all Things take Care that you do not ſpare Timber.'

As I have mentioned *Ramſgate*, I ſhall only now obſerve, that that Work was then going on with great Spirit: To me it was really wonderful to ſee with what Dexterity they handled great Blocks of *Portland* Stone, and with what Eaſe and Deliberation they laid them under Water. Mr. *Preſton* was ſo kind as to favour me with a rough Copy of their Plan, and I then obtained ſeveral, and afterwards collected many other principal Matters relative to it.

Seeing the maſterly Proceedings in this great Work, made me look upon my own little Project in a very diminutive Light. However, after ſtaying there two Days, and hearing many Remarks concerning the moſt commodious Situation for a Harbour in the *Downs*, I poſted away to take a curſory view of that Coaſt as far as *Dover*.

I have mentioned above, that the ſight of the Work at *Ramſgate*, had given me ſome ſort of Confidence in the Succeſs of my own Project; but I cannot help relating a very ſingular Incident that happened on my going down *Dover-hill*, which was ſo ſteep that I was obliged to alight and walk down, and my hopes of Succeſs at that Inſtant operating ſtrongly in my Mind, I chanced to eſpy a leaf of a School-boy's copy Book lying on the Road, I took it up and thereon found theſe Words, " *The more poſitive thou art, the more*

more wilt thou be derided if thou miſcarry." This ſhrewd, yet juſt Remark was ſo *a-propos* to the Situation of my Mind at that Time, that it made a powerful Impreſſion on it; and if it had no other Effect, it at leaſt made me thoughtful and reſerved.

I ſhall not relate the various Opinions of ſeveral judicious Perſons, whom I conſulted concerning my Incloſure, or *Coffer-dam*; but in brief, I purchaſed more Books in hopes of meeting with ſomething concetning it, as I found I could not acquire any practical Knowledge from profeſſed Artiſts. I purchaſed two Chain-pumps, three Double-ſcrews, ſix Jacks of different Sizes, two Drudging-engines, and ſeveral Sorts of Tarraſs, and went to *Leigh* near *Warrington*, to procure ſome Leigh-lime (which as I was informed, would ſet under Water as well as Tarraſs) picked up a few Labourers at *Liverpool*, and on the 23d of June returned to *Dublin*.

CHAP. IV. SECT. I.

Concerning COFFER-DAMS, *with a fortunate Incident relative thereto.*

ON my return to *Dublin*, I immediately ſet about to ſum up and re-conſider all the very little Knowledge I had acquired concerning Coffer-dams; the Reſult of which was, that after all I found myſelf in the ſame Predicament I was before. Not one Man had I ſeen or heard of, that ſeemed to be in the leaſt acquainted with the Subject; nor one Book that contained even that Word, or conveyed the leaſt Idea of the Conſtruction of it, except what I before mentioned; but fortunately for me, I went to enquire for ſome Books at Mr. *George Ewing*'s, and telling him of the dubious Situation I was in, he informed me his Son *Alexander*, was then on his Travels, and he believed by that Time in *Paris*. I earneſtly requeſted he would write to him directly in the moſt preſſing Manner, to procure me at any Expence, all the Books, Drafts or Plans, that could afford me any kind of Inſtructions for laying

laying the Foundation of a Bridge about 25 Feet under High-water, in a rapid River, and to ſend them with all Expedition.

He moſt zealouſly performed his Part, and it happened at that Juncture, Colonel *Belidor*, had compleated his 4th Volume of *Hydraulic Architecture*, which was ſent me, together with the other three Volumes; and alſo a perſpective View of the Men at Work in a Coffer-dam, at the Bridge at that Time rebuilding at *Orleans*. --- The Language I was a Stranger to; but on turning over the Plates, I quickly perceived his Conſtruction of Coffer-dams, as we now call our Incloſure. My drooping Spirits then inſtantly revived, and I immediately went on with my Work with Vigour, and entertained the moſt ſanguine Hopes of Succeſs.

SECT. II.

Concerning the Conſtruction of Batterdeaux, or Coffer-dams.

WE have already noted the *French* Method of laying Foundations in *Batterdeaux*, which is their technical Term for damming off the Water; and it is the very ſame of that practiſed by the *Romans*, as is before ſlightly mentioned by *Alberti Paladio*, and *Scammozzi*, which is tranſlated Incloſure; and I think there is no doubt, but that the *French* have not only retained, but improved and extended this moſt uſeful Method, which probably has never been acquired, at leaſt not much practiſed in any of theſe Kingdoms, or otherwiſe, there probably would have been ſome mention made of it in ſome of our Books; but particularly in ſuch as were relative to the building of Bridges, or the like Work in Water. They have indeed, of late tranſlated the Word Batterdeaux, and rendered it Coffer-dam, which I preſume, is a Word or technical Term not uſed, nor even ſo much as known in the *Engliſh* Tongue before the Year 1734; about which Time it was introduced in ſome Propoſitions concerning *Weſtminſter* Bridge; for if the *Engliſh* (who are ſo juſtly celebrated for Learning and Ingenuity) had been acquainted with this Word, or with this Method of laying Foundations for Bridges, it is not to be ſuppoſed, that

that the Authors of the univerſal Dictionary of Arts and Sciences, and innumerable other Books, would have intirely over-looked an Art of ſuch public Utility.

It was in the Year 1737, that the Act paſſed for building a Bridge at *Weſtminſter*, on which many Plans and Schemes were projected; but how to lay effectual Foundations, was the principal Thing that engaged the Attentions of the Commiſſioners. Mr. *Labely* propoſed to lay them in Caiſſons, but ſeveral ingenious Gentlemen moſt earneſtly recommended Coffer-dams: Now pleaſe to obſerve Mr. *Labely*'s Objection to Coffer-dams, taken from his Deſcription of *Weſtminſter* Bridge, Page 41.

Propoſition 3d, " Why could not the Foundations of the Piers have been laid by the help of Coffer-dams, ſuch as are called by the *French* Batterdeaux?" To which Mr. *Labely* gives the following anſwer.

" That if the Incloſure is not ſtrong enough in the inſide, it will not be able to ſupport the Preſſure of the external Water; but admitting it was ſtrong and ſtaunch, he calculates that the ouzing in of the Water through the Pores and Interſtices of the Gravel, looſe Clay or Sand, would amount to a Hole of ſix Inches Square, which, he ſays, is much under the Truth, and that it would give above 770 Tuns per Hour, which is more than 70 Men could pump out, ſuppoſing them to Work always with the ſame Strength both Night and Day; and more than 150 Men, or 30 Horſes could do, working as they commonly do." And proceeds, " All that I ſhall add to this Article is, that ſome of the Perſons who propoſed or eſpouſed this Method of making an Incloſure round the intended Pier with Dove-tailed Piles, and pretended to drain the Water from within, might remember how fruitleſs was the Attempt, or rather Experiment that was made of it in *Hide-park*, not many Years ago."

Note 1ſt, " As to his Aſſertion, that the ouzing would give 770 Tons per Hour." 2d, " That they might remember how fruitleſs was the Experiment not many Years ago." Pray does not this prove that we are not acquainted with this moſt excellent Method

of

of Working? And how neceſſary it is to have it cultivated amongſt us, I ſhall leave you to judge on what follows.

Now it is probable that the Story of *Columbus*'s Egg will occur to the Mind of the Reader, when he turns to Plate VIII. where he will ſee Colonel *Belidor*'s Conſtruction of a Coffer-dam, ſo clear and ſo intelligible, that from the bare Glance of an Eye, any common Journeyman Carpenter might readily comprehend it.

EXPLANATION *of* PLATE VIII. *Scale* 5 *Feet* 1 *Inch.*

Fig. 1, is the Plan of it with the ſheeting nailed on the Piles, juſt ready to receive the Clay; that Fig. 2, repreſents the Section of the Dam in the middle of the Bridge; A. low, and B. high Water marks, and it is in this Place 17 Feet broad, but that Breadth diminiſhes to 12 Feet up, and to 14 Feet down the River, as you may obſerve in the laſt Plate; and alſo, that the extreme Ends of it are let into the Quay Walls, ſo as the Clay of the Dam and the Earth of the Banks might unite together.

The Braces, C. are only to be uſed occaſionally, for all the Stages ought to be kept clear, and in Caſe any part of the Bed of the River ſhould prove ſofter than another, and the Dam inclines to one Side more than to the other, drive down the Pile e. into the Bed of the River D. and then by the help of a Rope and a Boat-hook, you may guide the point of the Shoe of the Brace-pile f. into a kind of Mortice, or a Hole made for it in the Pile e. at the Surface of the Bed of the River; and if you find the Preſſure is great (which is no Way improbable on ſome Ground) then you may Spike on the Slob or Plank g. and if you pleaſe alſo Spike it to the Dam at h. and all this you might do on the out Side of the Dam alſo; in Caſe the Water was 8 or 10 Feet deep, but it was Experience that taught me the Uſe of theſe Braces, and they were very ſerviceable to us.

I muſt alſo obſerve, that the Piles of Colonel *Belidor*'s Coffer-dam were drawn upright as theſe are, and that as I did not underſtand *French*, and could not conveniently get it tranſlated, I do not know what he wrote upon it; but this I am certain of, that the

Pl. 8.

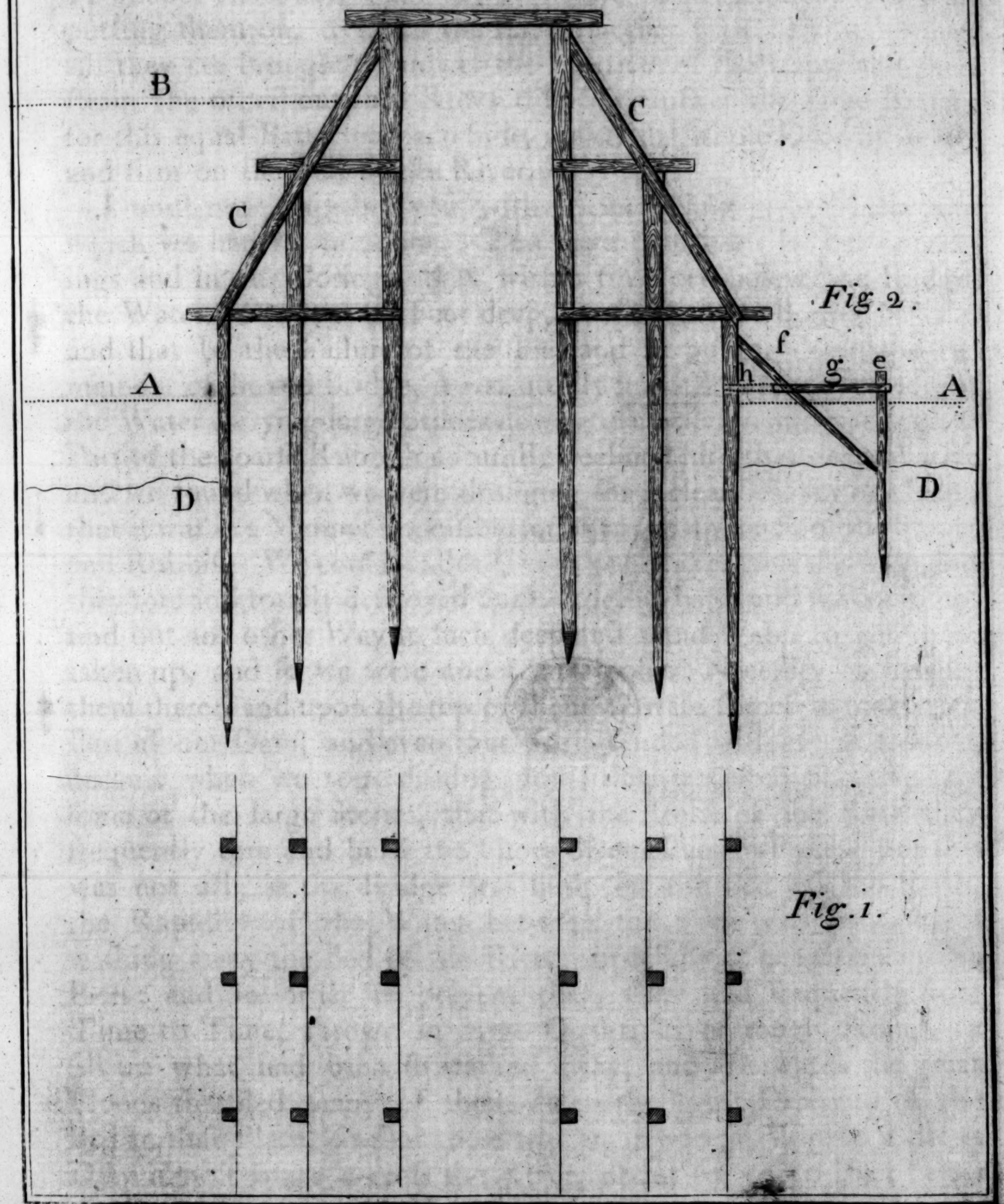


Fig. 2.

Fig. 1.

the Caps of the middle Rows of Piles, ought to be morticed 9 or 12 Inches narrower, than the Rows are in perpendicular, and in putting them on, to ſtrain the Piles together with a twiſted Rope, till they are brought to anſwer the Mortices of the Caps, and then ſtrain the other outward Rows till they anſwer the ſame Batter; for this equal Batter on each Side, makes the whole Dike ſit ſteady and firm on the Bed of the River.

I muſt now acquaint you with an exceeding great Misfortune which we had to ſurmount. You have ſeen both in our Soundings and in our Borings, that within 60 Feet below the Bridge, the Water was about 23 Feet deep, particularly at Boring N° 24. and that by the Failure of the Pier and in pulling down the remainder of the old Bridge, it was utterly impoſſible for us to prevent the Water carrying large Stones down the Declivity, and a very great Part of the coarſe Rubbiſh naturally declined into that deep Water; and we found when we were drudging for a clear Seat for our Dam, that it was in a Manner impoſſible for us to get up much of the Stones and Rubbiſh: We could, indeed, with our Brakes turn them up, but they tore and totally deſtroyed our Drudging-bags, and we could not find out any other Way in ſuch deep and rapid Water to get them taken up, and ſo we were under an abſolute Neceſſity of leaving them there; and upon the top of them we were forced to make that Part of our Dam, and even that was attended with much trouble, becauſe when we were driving our Piles, we often happened on ſome of the large Stones, that with the ſtroke of the Ram they frequently tore and burſt the Shoes of our Piles to Pieces; but this was not all; as the Bridge was built on the Bed of the River, the Rapidity of the Water between the Piers was continually waſhing away the Bed of the River, eſpecially at the Stern of the Piers; and in order to prevent that, they had frequently from Time to Time, thrown in large Quantities of rough Stones, to fill up what had been ſo waſhed away, and afterwards the great Floods tumbled many of them down the great Declivity of the Bed in that Place, ſo that there was, as it were, a Wire or a Stone Dike almoſt quite a-croſs the River, about 65 or 70 Feet below the Bridge, which we did not in the leaſt perceive, nor ſuſpect,

when we were boring, as we did not bore any to the Eaſtward but N°. 22, 23, and 24. and by their filling up and raiſing the Bed of the River, they alſo concluded, that they had thereby taken off the Rapidity of the Water: In ſhort, the force of the Water had carried away every Thing it could, and left little behind it but coarſe Rubbiſh and Stones, which were juſt like a *French* Drain under our Dike, and the great Wonder is, that we were in any Ways able to conquer it, nor ſhould we have been able to do it but by this one Method. We drudged all we could come at away, as clear as we could from the Back of the Dike, and immediately filled up the Vacancy we ſo made, by throwing in ſeveral Floats of Clay, which united with the Clay of our Dam. If you ever happen in any ſuch diſtreſſing Circumſtances, I adviſe you to ſpare neither Money nor Time, to clear the Seat of your Dam of all ſuch looſe Stones and coarſe Rubbiſh, before you begin to make your Dam, and then you will not have the leaſt Trouble nor Anxiety about it afterwards; for of all the Methods that have been invented, I believe there are none ſo ſecure, nor ſo pleaſant to execute, as that of building and laying your Foundations on *Terra Firma:* Nor is there any ſort of Difficulty in accompliſhing it in any reaſonable Depth of Water, provided you work on freſh maiden Ground, that has not been fouled or incumbered with Stones.

I muſt further adviſe you if ever you have a Bridge to build in pretty deep Water, do not be diſcouraged by Mr. *Labely*'s erronious Calculation, of 770 Tons per Hour. --- The Circuit or Extremity of our Dam, was much greater than any that he would want for one of his Piers, upon which he made his Calculation; and I affirm that notwithſtanding the Roughneſs and Looſeneſs of our Ground, after we got our Dam ſtaunched as before mentioned, we wrought with great Eaſe and Pleaſure at the North end, which was upwards of twenty one Feet under our high Water mark, and for many whole Tides together, not a ſingle Hogſhead of the external Water ever annoyed us; and I am very ſure that by the Methods hereafter directed, you may lay a Foundation thirty Feet under high Water mark with great eaſe, provided as before-mentioned,

tioned, you have clean freſh maiden Ground to work upon in a moderate River.

CHAP. V.

Concerning Pile and Pump Engines.

BEFORE I treat of the Pile Engine, it is neceſſary to inform you, that in freſh Water Rivers of 5 or 6 Feet or more in Depth of Water, you probably may have very little trouble in making your Dams; recollect how ſlightly *Alberti* ſpeaks of getting a few Hedge-ſtakes and the Branches of Trees, *&c.* to make them, and even in the upper end of our Dam, neither the Trouble nor the Expence was of any great Value, which we performed after this Manner. We floored one end of a ſmall Float, and on that ſet two Treſſels of about 4 Feet high, and in driving the middle Rows, we erected another Stage of the ſame Height over the firſt, and drove them with double-handled Mauls, and probably it will not be neceſſary to ſhoe them with Iron, but juſt point them or burn the Points of them in a Fire to harden them, obſerving to begin at the Head of your Dam, and drive the out-ſide or in-ſide Piles juſt as the Tide anſwers, and always take Care to keep your Float tightly moored up to your Work, for which purpoſe it may be neceſſary to have a Sea-faring Man to help you: Let your Mauls be well hooped and ſtrapped with Iron, otherwiſe the Hoops may be liable to come off with the driving: According as you drive in your Piles (if the Water be rapid) it may be very proper to nail Pieces of Slabs or the like, to keep them together, leſt the Current ſhould diſplace them; and after this Manner you may do very effectual Work without an Engine. However, I ſhall give a Draft of ours, which I took partly from *Vaulou*'s, and partly from *Belidor*'s Deſigns, as follows.

EXPLANATION *of* PLATE IX. *Scale* 4 *Feet* 1 *Inch.*

This Plate ſhews the framing of the Platform of the *Pile-engine* in Fig. 1, where in the dotted Lines *a.* ſhew, that after it is floored, there muſt be Ledges nailed on to give firm hold to the Feet of the Men that work it; *b.* is the Block into which a Braſs Socket is to be fixed for the Axes to ſtand upon, and this Block muſt be ſlided over to *c.* which you will find further deſcribed in the 11th Plate; *d.* is the Ladder to bring you to the ſecond Floor, *viz.* Fig. 2, in which note that *e.* is another Block to be framed in its Place with a Collar of Braſs, left open quite through the Block, over which there muſt be a Shutter or Lid to keep it free from Dirt, or to greaſe it when neceſſary.

EXPLANATION *of* PLATE X. *Fig.* 1. *ſame Scale as Plate* IX.

This repreſents the Front of the Engine, with the Ram and Follower reſting on the Head of the Pile. Fig. 2. is the Follower playing in its Grooves by a Scale of 1 Inch = 1 Foot. Fig. 3. (by the ſame Scale) ſhews the Section of the Follower and Ram, ſeemingly juſt ready to engage one another, as alſo, how the Tongs are opened by the two inclined Planes, a. a.

EXPLANATION *of* PLATE XI. *Fig.* 1. *Scale* 4 *Feet* 1 *Inch.*

Repreſents the Section of the Engine from Front to Rear, wherein note, that the Block *b.* above-mentioned, is occaſionally to ſlide over to *c.* and one half of the Block *a.* muſt be firmly bolted down to the Floor, and the other half opens and ſhuts with a Hinge about the Axes, with Semi-braſs Collars, obſerving to leave proper Room above your Drum-head, for the Axes to lift ſo high as to clear the Socket of the Block *b.* at any Time, when you have occaſion to repair it; *d.* is the Spring that locks the Drum to the Shaft.

Pl. 9.

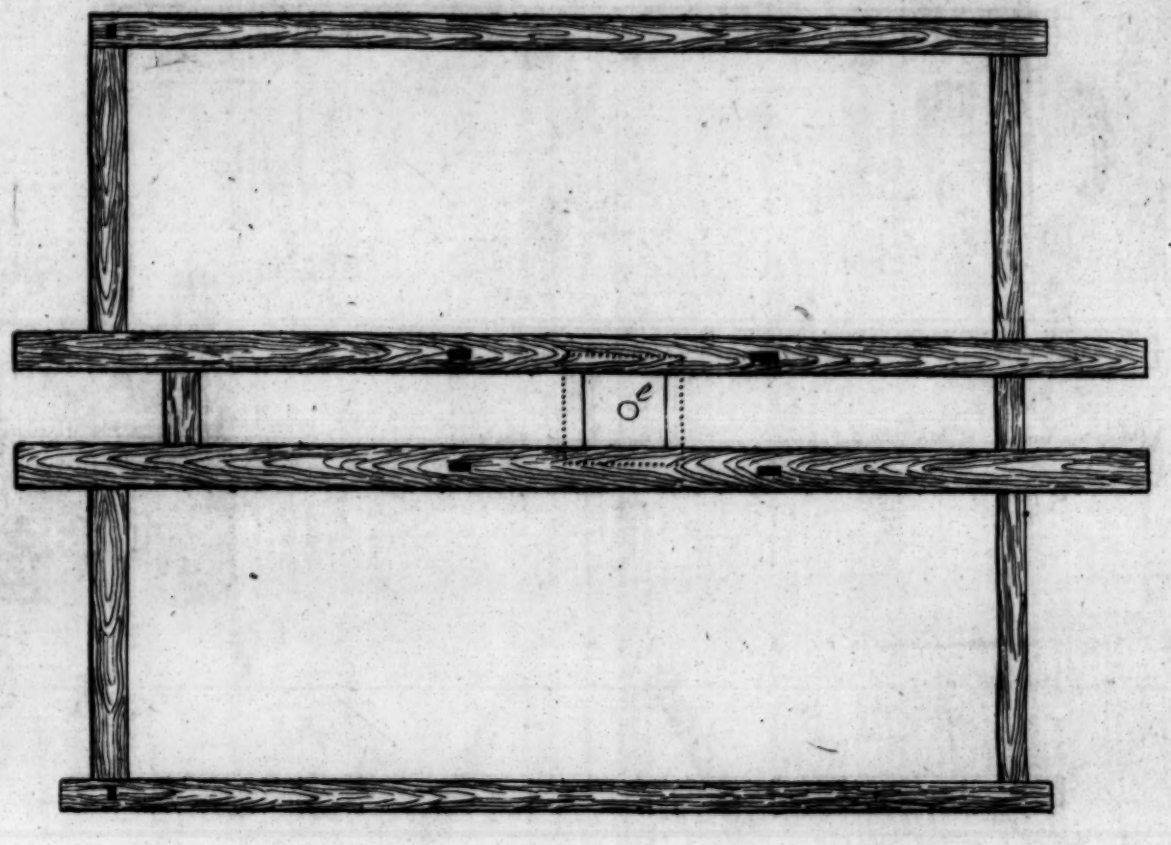


Fig. 2.



Fig. 1.

Pl. 10.

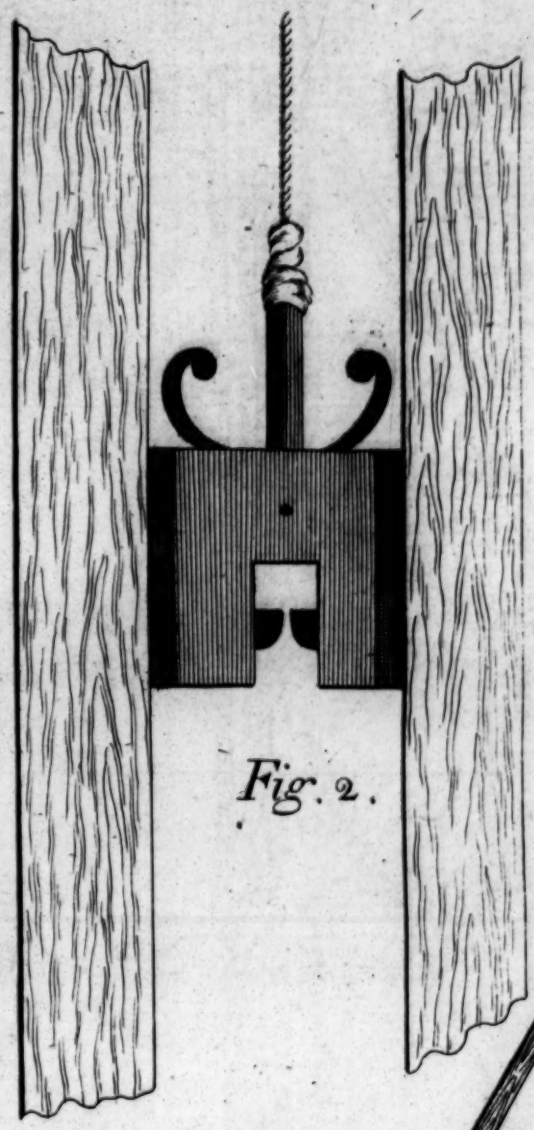


Fig. 2.

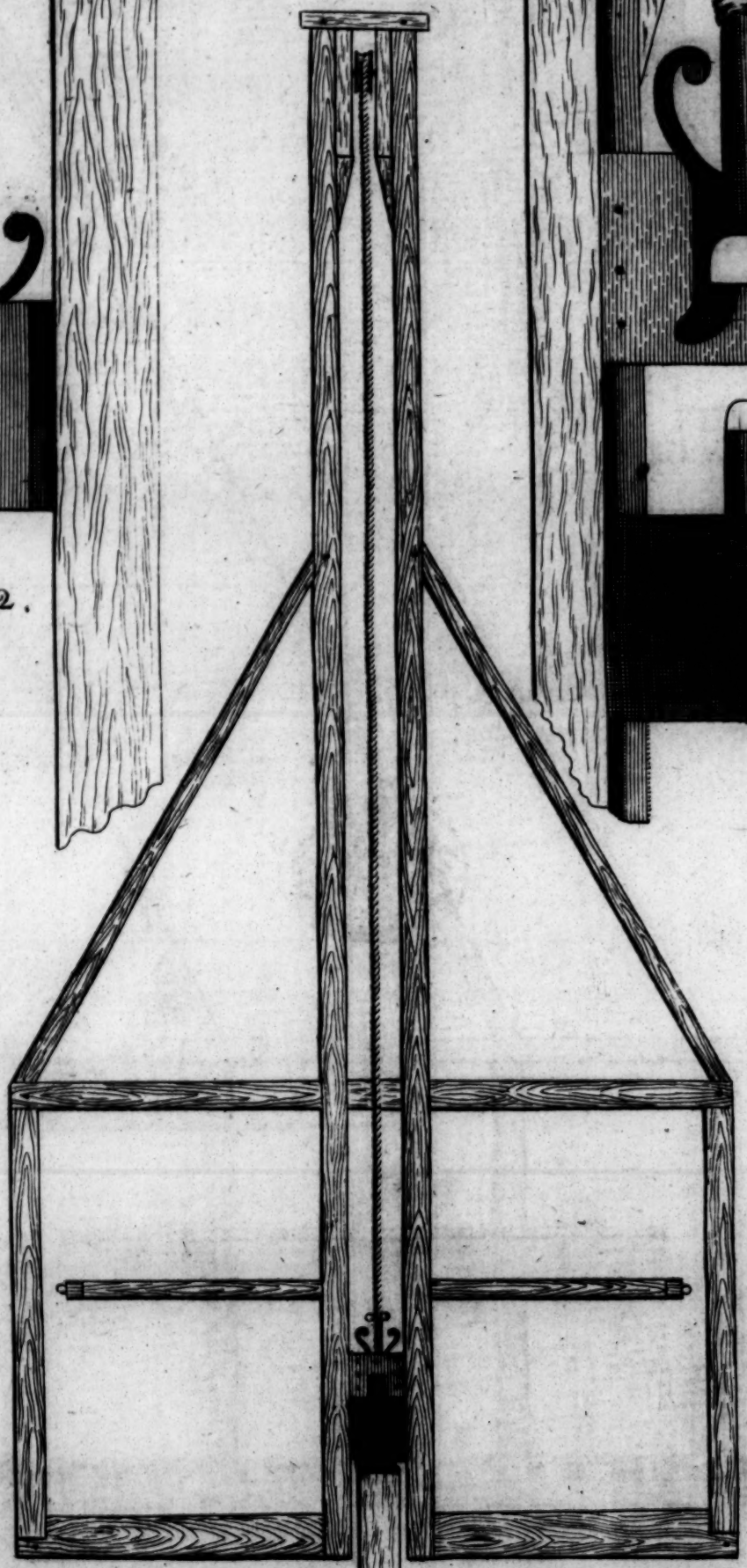
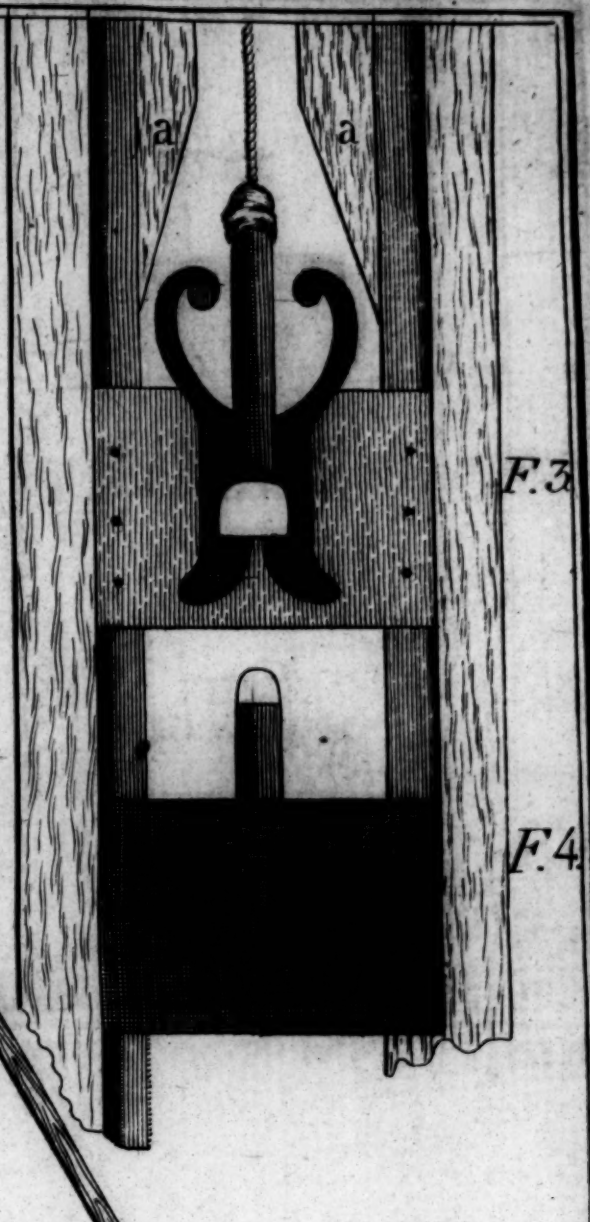


Fig. 1.



F. 3.

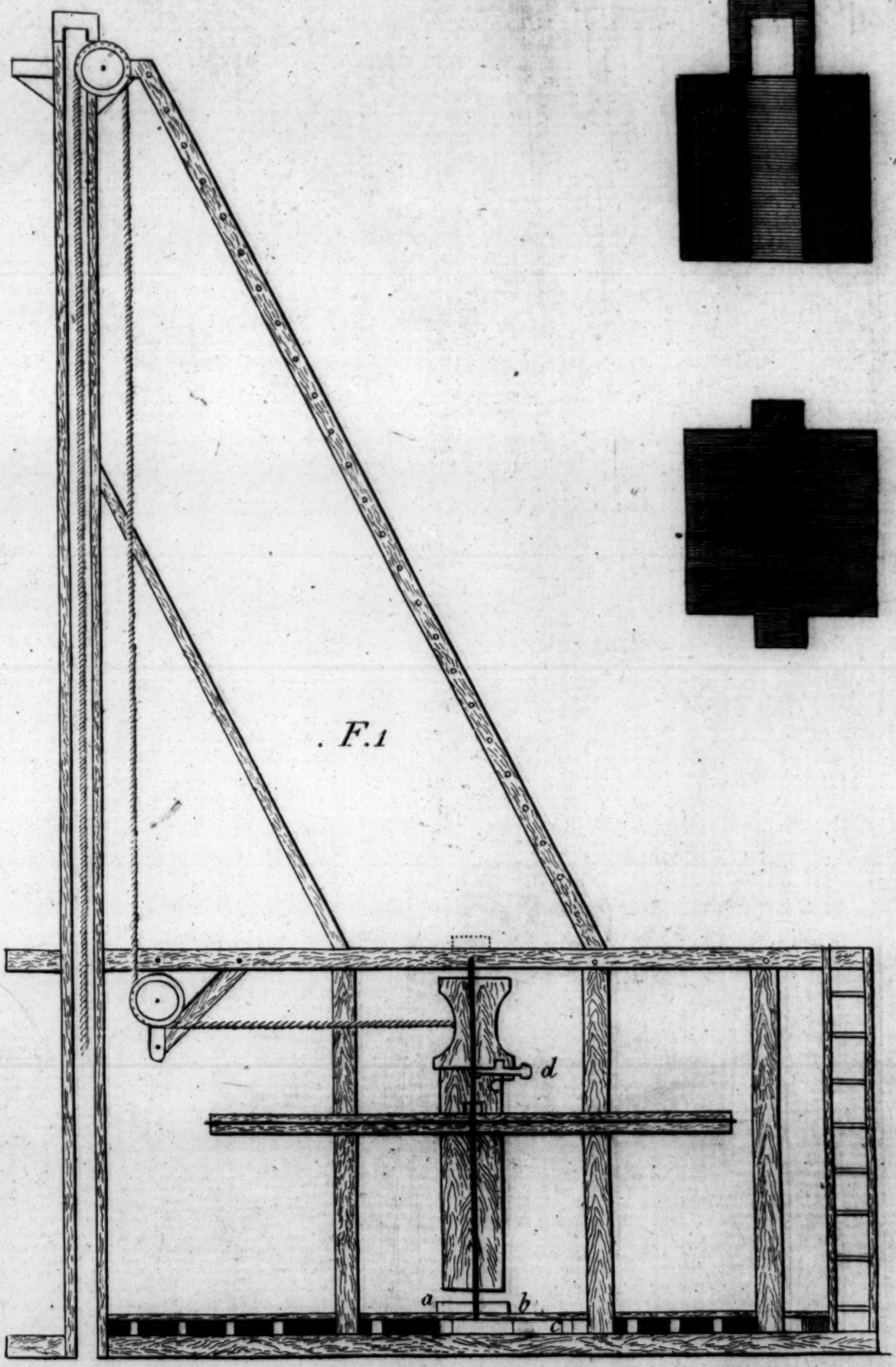
F. 4.



P. II.

F. 3.

F. 2.



F. 1



Pl.12.

Fig.2.

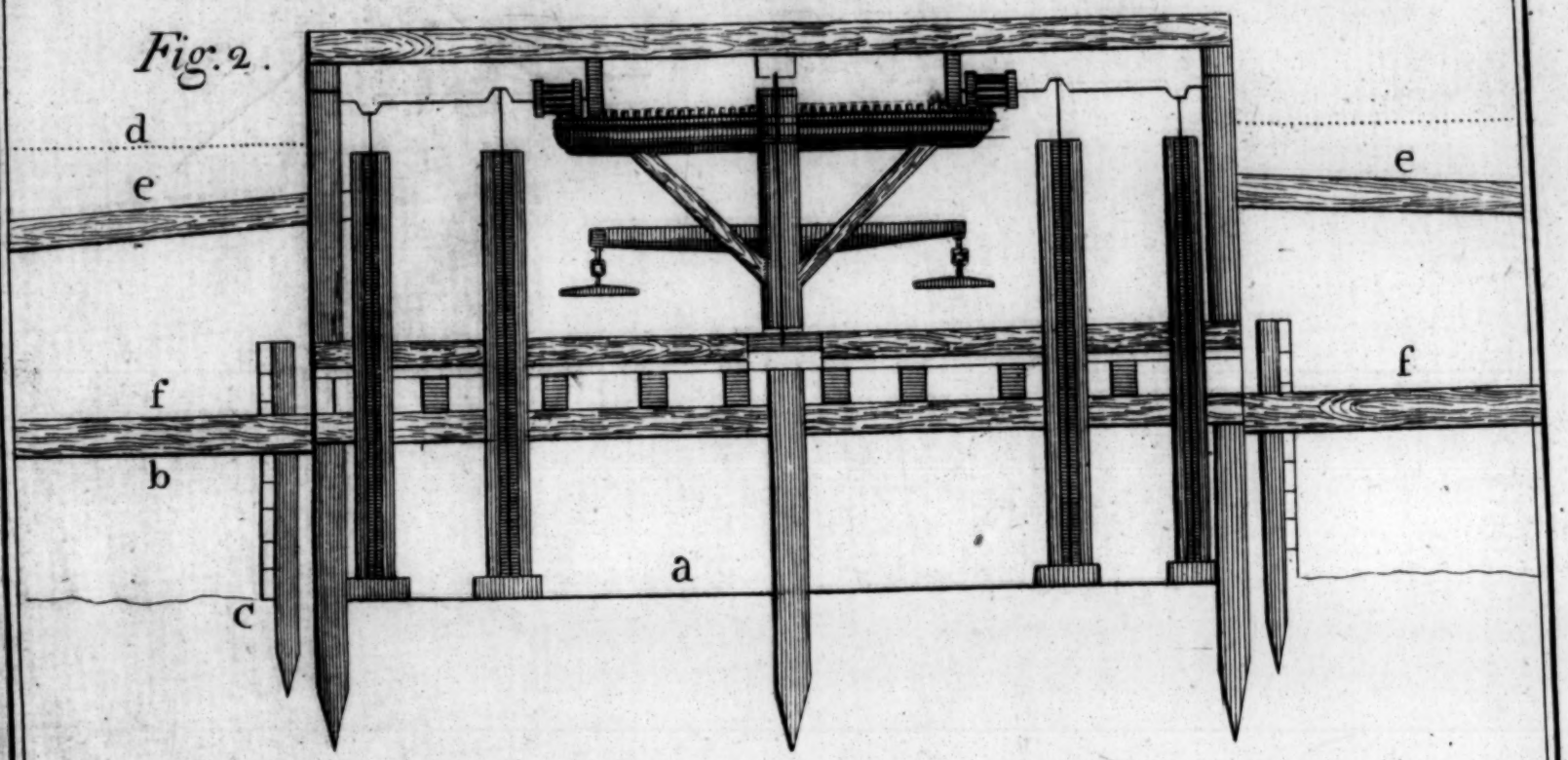
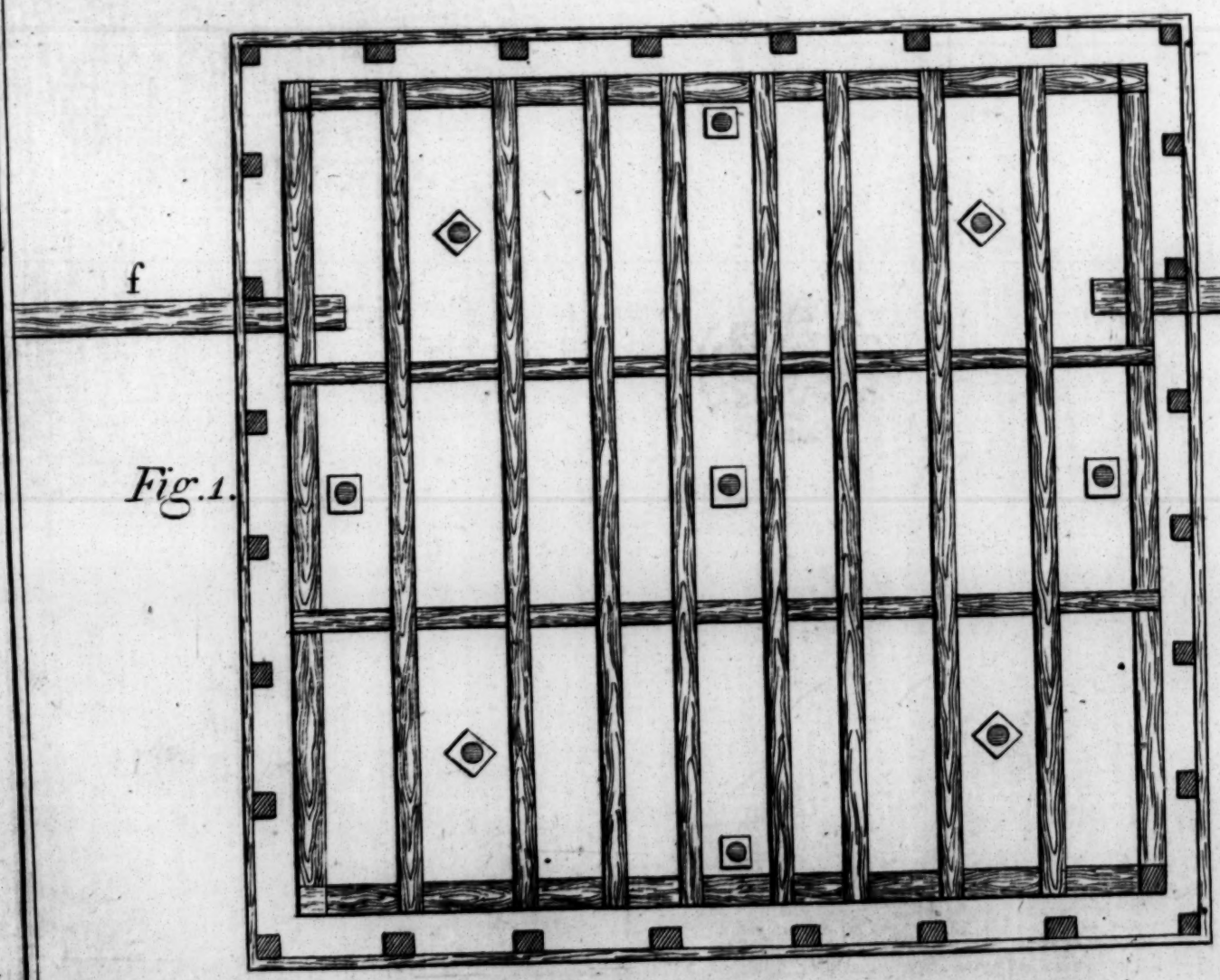


Fig.1.



Shaft. Fig. 2. (by an Inch to a Foot) is the Plan of the Ram; and Fig. 3. is the Upright of it with the Staple, that the Tongs take hold of. This Ram is only four hundred and a half, which may be fully ſufficient for theſe or the like ordinary Occaſions; and for more weighty Work, you may on the ſame Principles proportion the Size of the Ram to the Size of the Engine which you think you will want.

EXPLANATION *of* PLATE XII. *Scale* 8 *Feet* 1 *Inch.*

Fig. 1. is the Plan of the Timber of the Floor of the *Pump-Engine*, with the Situation of the 8 Pumps, and Centre or Socket of Braſs, on which the main Body plays.

Fig. 2. Section of the Engine, wherein note, that a. is the bottom of the Pool; b. Low-water Mark; c. is the Incloſure of Piles and Boards that keep up the Banks of the Pool; d. High-water Mark; e. open Gutters, that convey the Water from the Pumps over the Dike; f. both in Fig. 1. and Fig. 2. and D. in Plate VII. are the Trunks that either carry off the interior, or let in the exterior Water occaſionally at Low-water Mark, to which there were Sluices fixed in the middle Stage of the Dike, that were wound up and down by a Jack.

From my firſt forming an Idea of the Incloſure, my Mind was conſtantly oppreſſed with the dread of its burſting in upon the Men, when they were at Work in the Pit as before-mentioned; from which intolerable Anxiety, I was relieved by contriving theſe Trunks. I cannot tell whether Colonel *Belidor* uſed any ſuch Thing, becauſe as I before obſerved, I was ignorant of the Language he wrote in; but I am well aſſured, and you will hereafter find, that they were of infinite Service to us. The other Parts of this Engine are obvious, as indeed, there is ſcarcely any good Millwright but what may comprehend and execute the whole Conſtruction of it.

Having now to the utmoſt of my Power fully conſidered every Thing relative to this Work, I ſat down, and by the Aſſiſtance of my Brother *John*, made an Eſtimate of the Expence, ſuppoſing the

Balluſ-

Balluſtrade to be made of Fire-ſtone; and we found it amounted to twenty thouſand Pounds, and I promiſed that I would not exceed twenty thouſand five hundred, for we allowed the five hundred for Incidents; and I computed, that within, or about the Space of two Years, from the Day upon which I ſhould ſtop up the old Bridge, that a ſafe new Road might be made over the new Bridge for Carriages; and upon theſe Calculations and on mature Deliberation, I made the following Declaration, not only to the Overſeers with whom I treated, but alſo, promiſed to the Lords Juſtices, to the Committee of the Houſe of Commons, and to the Public in ſeveral Papers to this Effect. 1ſt. That I would build them a Bridge that ſhould ſtand as long as a little adjacent Mountain called *Sugar loaf-hill.* 2d. That the Expence ſhould not exceed 20500 *l.* 3d. That I would have a Road opened for Carriages over it, within or about two Years from the Day of my ſtopping up the old Bridge as above-mentioned; but I did not any otherways bind myſelf to the Performance of any of thoſe three Articles, yet notwithſtanding, I looked on myſelf to be as much bound to the Performance of them, as though I had engaged for them under my Hand and Seal, and ſtaked any little Reputation I had acquired, faithfully and effectually to perform them to the utmoſt of my Power.

CHAP. VI. SECT. I.

Of demoliſhing the old Bridge.

WE began on January 19th, 1753, to ſtop up and demoliſh the Bridge, and take down the Equeſtrian Statue of King George I. which had been put up in 1722.

February 19th, we drove the firſt Pile of the Coffer-dam.

In pulling down the Bridge, we began at the South, and took in the largeſt half of it in order to open and deepen that Side, to let the whole Current run there. In doing of this, I found it neceſſary to make a temporary Dam, to turn the River to the North, in order to lengthen the Time of Ebb, and clear away the old Ruins, *&c.*

After

After this Dam was made, we were going on very ſucceſsfully till the 28th of April, when there came down a pretty ſtrong Land-flood, which obliged me to take the Men off that Part of the Work. I then ſtood on the northerly Part of the Bridge, dreading the Fate of our poor little Dam, when I eſpied the Water within Side of it grow very black, the cauſe of which I well knew to be the blue Clay burſting out, and I hurried down to it in order to ſee if there was any Poſſibility to ſave it; but the very Moment I had got on the top of it, I found the whole riſe up under me, and had not above a ſecond of Time to ſave my Life; for the Floor that was on the top of it turned immediately down, and the Points of the Piles roſe up, and notwithſtanding the Activity of the Men, great Part of it was carried down the River; but this fright was of much uſe to me, for as the cauſe was the Floods getting in under the Clay, I was ever after on my guard by making our great Dam in ſuch a Manner, as might reſiſt the Force of any Land-flood or Torrent.

May 31, the laſt of the Piles of the Coffer-dam was drove, and *June* 4th, we began to fill the Clay into it, and the ſame Day having taken up all we could of the Foundations, we began to deepen it by drudging.

SECT. II.

Deſcription of the Foundations.

THE Foundations of this Bridge, or rather the Piers of it as before mentioned, were built after this Manner. They made Frames of Oak of 9 or 10 Inches Scantling, the exact Shape of the Pier, with rough two Inch Planks of Oak Dove-tailed acroſs it, in every three or four Feet and pinned to the Frame, and on theſe Planks they ſtretched other Planks Length-ways but not ſo thick. Theſe Frames ſo made, they dragged to their Birth, and let them reſt upon the natural Surface of the Bed of the River. The Piers being extremely groſs, increaſed the Rapidity of the Water between them, and the Bed of the River (as you have already

ready ſeen) being ſharp Gravel, the Floods ſwept it down as before-mentioned, and indeed, the only Thing ſurprizing is, that it ſtood ſo long.

Now I am come to one particular Circumſtance, which I recommend to your ſerious Attention, as I ſhall hereafter endeavour to draw ſome uſeful Inferences from it. After we had got ſome of theſe Frames taken up, particularly the third, we found under the inner Part of it, a ſmooth Floor of clean ſharp Gravel, hard and firm under our Feet; but when we thought to go on with filling the Floats with it, to carry it away, as we had done in the Bed of the River between the Piers, we found it very hard, and as the Shovel could not move it we tried the Pick; but when we had got a little further into it, the Pick made little Impreſſion upon it, and when we got further into it, we found that we had no other Way to break it, but by undermining it, and then break it off in Pieces with the largeſt Sledge we had. The middle of it was an actual Petrification of about a Foot thick, but not ſo hard in the bottom as in the top. Some of the Piers were much more petrified than others, and particularly this, as being better guarded by the Baſe of the Effigy, and having imbibed the petrifying Qualities that ſoaked from it. The Grit or Grain of it greatly reſembled that of a Mill-ſtone; but the Colour was juſt the ſame with the Bed of Gravel it lay upon. Where the Gravel partook of Mud, the Pier that lay on it was not near ſo hard, and thoſe Piers did not petrify at all that lay on Beds that were not gravelly.

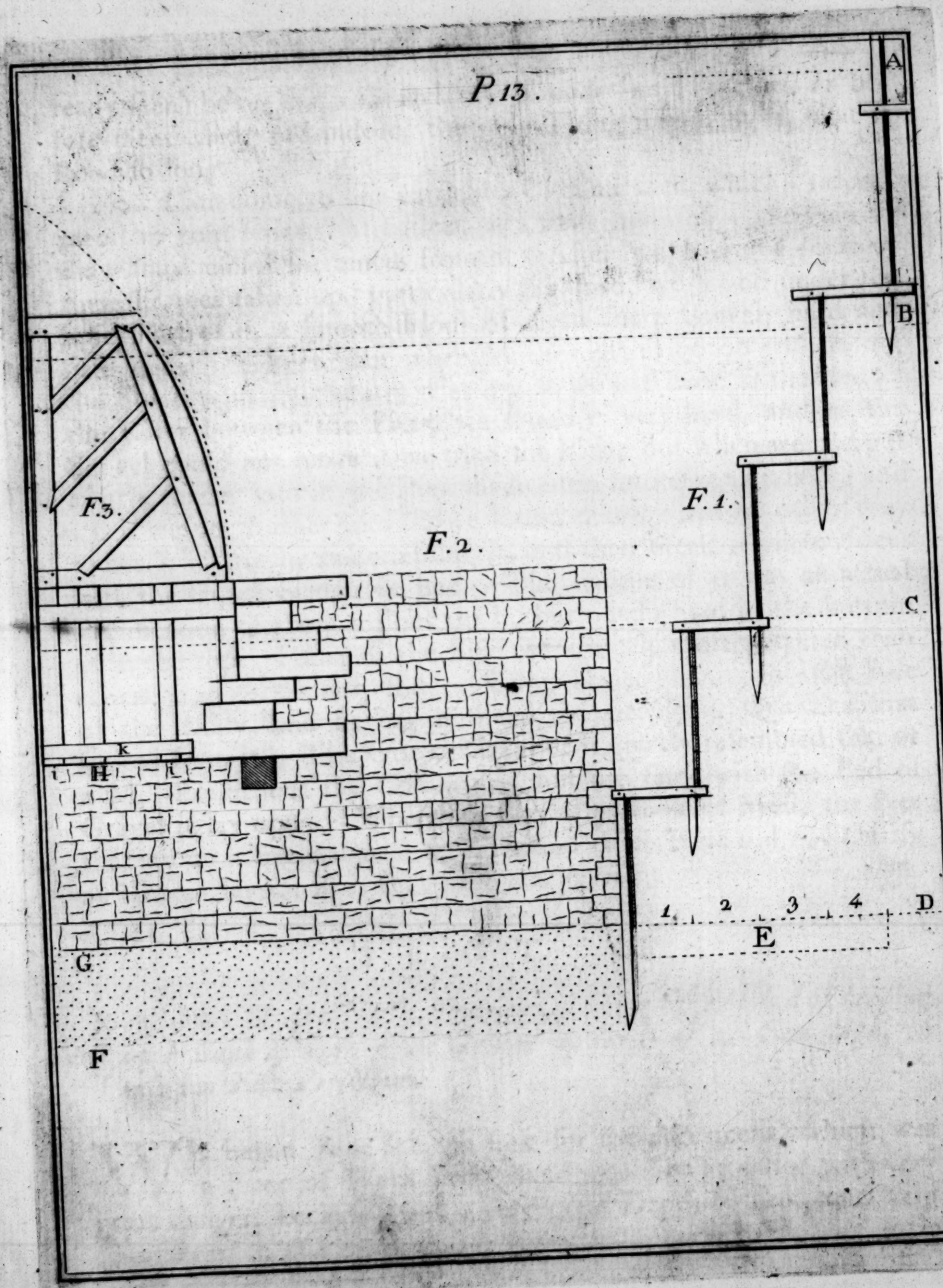
SECT. III.

Breaſt-work for the North Abutment, ſhewing the Method of keeping up a Bank of looſe made Ground upwards of 30 *Feet high, on only ten Feet Projection.*

WE began *June* 8th, to ſink for the Abutment, which was a Piece of Work I was afraid would be attended with very great danger, becauſe I had a very great Depth to ſink, and very little



P. 13.



little Room to ſink upon, without depriving the Public of the uſe of the Carriage Way.

EXPLANATION *of* PLATE XIII. *Scale* 5 *Feet* 1 *Inch.*

In this Plate, Fig. 1. repreſents the Method I took to keep up the Breaſt of the Bank, wherein note, A. Pavement. B. High-water Mark, which is 9 Feet 4 Inches from the ſame. C. Low-water Mark = 10 Feet. D. Bottom of the Pit 11 Feet, that is = 31 Feet 4 Inches. E. Is the whole Projection of the Breaſt-work, which is 10 Feet, and that I divided into 4 equal Parts, allowing 2½ Feet to each Stage. Having ſtrained a Line at right Angles to the intended Bridge, and 10 Feet from the back of the Abutment, we ſunk about three Feet, and then drove in a range of 4 Inch Piles cloſe to the Bank; then with paving Hammers we chipped off ſo much more of the Bank as juſt barely admitted the ſheeting to ſlide down between the Bank and the Piles; and when we had ſunk 8 Feet in this Manner, we made our firſt ſet off 2½ Feet, and proceeded in the ſame Manner as you may perceive by the Draft; but after we had got down to the third Stage, we always kept Braces againſt the Breaſt-piles, which we removed down according as we ſunk; and notwithſtanding the almoſt conſtant running of Carriages, and the Banks being all made Ground, there did not fall one Handful of it in upon us. When we had got down to about the third Stage, or a little under Low-water Mark, we had all above us compoſed of various ſorts of made Ground; but from and about that level we found the Ground begin to incline to fine ſandy blue Clay, ſometimes mixed with Shells, and ſometimes with Leaves, which we took to be Bay-leaves, all of which, we concluded had in former Times been left there by the Sea and River, becauſe we got in it a ſmall Tree almoſt rotten, with ſome of the Branches ſtill upon it; at the Butt it was about 4 Inches Diameter, but no one could tell with Certainty what ſort of Wood it was of; from all which, I concluded that I did not raiſe any freſh or natural Earth.

It is not my Intentions to give a minute Detail of all the various Circumſtances relative to our Proceedings, for that, perhaps,

would be more tireſome than inſtructive; and therefore, I only give a conciſe Abſtract of a few Particulars taken from our Diary, in order to convey a juſt Idea of the whole of that Work; but having made one very extraordinary Diſcovery in this Place, which alarmed every Man in the Work, and greatly ſurprized a vaſt Number of Gentlemen that ſaw and examined it, I ſhall relate the principal Parts of it in the next Chapter, and reſerve the Explanation of Fig. 2. for a more convenient Opportunity.

CHAP. VII.

An extraordinary Diſcovery at eleven Feet beneath Low-water Mark.

HAVING got ſome Part of the North End of the Pit ſunk down to about ten Feet beneath Low-water Mark, and quite free from Water, except ſome ſmall Quantity that ſoaked from the Bed of the River, which was then about the ſame Space above us, and that we conveyed into the S. E. Corner for the Screw-pump; the Men that were ſinking for the Land Abutment perceived one Spot in the Ground that grew very wet, but did not much regard it; but in ſinking the next Spade which was about a Foot deeper, when they had laid open that wet Spot, we were all greatly alarmed by the very ſtrong boiling up of the Water juſt in that Place. I ſent immediately for my Book of Borings, and found that wet Spot was Boring N°. 28. I immediately called for one of the Boring-pipes, and had it drove down to the Rock, and the top of it was 3½ Feet above that Floor, on driving of which the boiling entirely ſtopped. This gave us ſome Spirits, and the Men went on with their ſinking that Floor, but at this Time the Tide was at Ebb; but when the next Tide roſe to about ſix Feet, it began to boil over the Head of the Pile, and increaſed in force as the Tide roſe, and ſo greatly wet the Work that we found it adviſable to plug up the Pipe, and ſo we continued to hurry on the Work, without taking any further notice of the boiling, except looking on our *Jetteau* as a Matter of Curioſity, which during the Time

Time of High-water and after it, when we would pull out the Plug, would play upwards of a Foot above the Head of the Pipe with great force.

The Rev. Doctor *Hudſon*, who was a very curious and conſtant Obſerver of our Proceedings, came to the Work the next Morning, and I brought him with ſeveral other Gentlemen to the Work, to ſee our curious *Jetteau*: He called for a Glaſs, and they all taſted, ſmelled and attentively obſerved its Colour. They then dropped a Piece of Silver into the Glaſs, which was ſoon turned to a dark yellowiſh Colour; and at Length, they all concluded that it was a mineral Spa, and adviſed me to ſend directly for Doctor *Rutty*, for whom I went myſelf, and he cheerfully came with me, the Gentlemen waiting for us: He tried all the before-mentioned Experiments over again, and acknowledged, that it ſeemed very like the Water of *Swaddling-bar*; but concluded, that any Sea-water that partook of putrid Water, running from a foul Sewer, might have the ſame Effects that had, and he deſired me to ſend ſome of it home with him, which I accordingly did.

This Affair engroſſed my whole Attention, and put me upon making the following Experiment. See Plate 4. Boring N°. 28, and ſee that N°. transferred to Plate 5. which is the Boring mentioned above. I then had two other ſimilar Pipes drove at ten Feet diſtance from it to the Eaſt and Weſt, *viz.* 29 and 30, and I bored them in the like Manner at Low-water, and as the Tide came in, I found the Water riſe in all the three Pipes exactly alike, and at or ſoon after High-water, they all played together when we took out the Plugs, near a Foot above the Heads of the Pipes, which were all on a level; and as the Tide fell, they abated in their Force, but never ſunk lower than the tops of the Pipes, which as I ſaid above, was 3¼ Feet higher than the bottom of the Pit, and conſequently 7½ Feet under Low-water Mark.

The next Morning Doctor *Rutty*, and Doctor *Hudſon* came to the Work, where they met the Gentlemen that were there the Day before, and he, Doctor *Rutty*, then aſſured us, that it was no Species of Spa-water, but he believed, a large Body of ſubterraneous Water, that ran along on the Surface of the Rock, and communi-

cated with the Sea-water, and partook alſo, of the foul Waters of the Bed of the River and the Sewers. He then produced us as much Salt as would cover a Shilling, which he ſaid, he had extracted from one Pint of that Water, which was not near ſo much as a Pint of Sea Water would produce; and concluded with giving me this friendly and uſeful Caution, "take great Care that you do not let that Water break up upon you, for if you do, you will never conquer it."

This Opinion of Doctor *Rutty*'s coroborating with my own, it was inſtantly circulated among all the Men in the Work. They all unanimouſly joined in exerting themſelves to the utmoſt of their Abilities; for that Water alone, was not the Cauſe of our Anxiety, as we were at that Time thirty-one Feet deep under the Surface of the Pavement, which was within ten Feet of being perpendicular over us, and all being made Ground, with a fine Sea ſandy bottom, which notwithſtanding all the Precautions we had taken in ſinking and ſhoring up our Breaſt-work, we well knew, that if the ſmalleſt Quantity of Water ſhould then get into the Pit, it would moſt aſſuredly ſap and ſoften that fine Sand, which together with the continual ſhaking of the Ground by the Carriages, would render it impoſſible for us to prevent its burſting in upon us, and in all Probability pull in the Corner-houſe along with it.

Hereupon we agreed, that it would be beſt and ſafeſt for us to deſiſt from ſinking any deeper, though that was no ſmall Diſappointment to us, as we then had thoughts of going down to, or very near the Rock, nor otherwiſe had we any Difficulty to encounter with in accompliſhing it; for the Floor we were then levelling and clearing out next to the Bank, was perfectly free from Water, except what little ſprang up with the three Pipes; but remembering Doctor *Rutty*'s Caution, which I knew to be well founded, I proceeded with all poſſible Expedition to make the Maſons ſecure the bottom of the Breaſt-work.

September 23, The Maſons began to lay the thorough Foundation, but particularly to ſecure the bottom of the Breaſt-work, which extended about 15 Feet from the Bank, and in the mean Time the Labourers were clearing out and levelling about 20 Feet more,

more, which being juſt accompliſhed they were hurrying in Stones to be ready for the Maſons, except one Man, who was left to throw out and level ſome ſmall Matter which they left undone; but all the alarms and frights we had met with, were nothing to a freſh Diſcovery which that Man firſt obſerved; the Floor (which was clean, ſmooth and dry) opening, I was inſtantly called, and when I got on the Spot, could clearly perceive the Ground ſwelling up and opening, (See N°. 31, in Plate V.) and it ſoon extended to about the Length of 10 Feet, turning rather ſoutherly at the Weſt End, and the Crack or Opening was about three or four Inches wide in the Middle. The Tide was then about ten Feet high, and in the Middle of the Crack we found the Water beginning to ſpring up, which gently increaſed to about a Foot Diameter, and ſprang pretty faſt. I called for another Pipe of the ſame Length, and had it drove down in the Centre of the Ebullition, or Boiling up, till it came to the Rock, and having bored and cleared it as before, which eaſed and gave it vent, we found the Water riſe up, and in Fact the very ſame ſort as came up in the three former Pipes, and to the ſame level, altho' this Pipe was 17 Feet to the South of them; and we plugging up this Pipe alſo, the Men did all in their Power to get in Stones and Mortar ready for the Maſons, and in the mean Time the Water that ſprang up through the Crack, roſe 18 Inches deep in the lower Part of the Pit; but providentially we then had the Maſonry built above ſix Feet high againſt the Bank; but when the Ebb came it deſiſted, and we ſoon got out the Water, and laid the largeſt and flatteſt of our Stones upon the Crack, ſpreading ſome Litter under them, and before the next Tide had that Part of the Foundation almoſt as high as the other; for, from the Time of our getting the Bridge taken down to High-water, we wrought both Night and Day, without one Minute's Intermiſſion, as we had two ſets of all ſorts of Men that relieved one another alternately every eight Hours, not excepting even Sundays, when our urgent Occaſions required it: Yet, notwithſtanding we had luckily conquered that ſubterraneous Water at ſo critical a Time, it never failed every Tide, whilſt we wrought in that Pit to contribute greatly to the increaſe of the Pump-mens Labour; but as

we

we wrought with unremitted Perſeverance and great Expedition, we moſt fortunately prevented its burſting up upon us. And of this I am well aſſured, that if we had not that Inſtant loaded that opening of the Ground, the ſubterraneous Water would certainly have broke in upon us, and if it had, there could have been no Kind of Poſſibility of ever building a ſubſtantial Bridge in that Place, conſidering the Condition that every Thing was then in, and ſo many thouſand Pounds worth of Labour and Materials would have been totally loſt, and our then hopeful Projects entirely at an End, as Doctor *Rutty* had told us.

CHAP. VIII.

A Continuation of the Abſtract of our Diary, and laying the Foundations of the North Pier, 21 *Feet beneath the uſual High-water Mark.*

WE made the firſt Trial of our Coffer-dam on *June* 27th, and it kept out 3 Feet 6 Inches of that Tide. *July* 3d, we ſcrewed down the Sluices when it was High-water, and kept them down till half Ebb, in which Time the Water in the Dam fell three Inches, and thus we tried and proved its Stanchneſs ſeveral Times, both backward and forward; but the South Eaſt Corner of it that ſtood on the great Depth of Stones that had been carried down by the Floods into that deep Pool, was like a *French* Drain (as before-mentioned) which we began to deſpair of ever getting made even tolerably ſtanch.

July 7th, we ſcrewed down the Sluices at low Water, and before high Flood, diſcovered that the Tide Water had wrought its Way in under that South Eaſt Corner through the Stones and Rubbiſh of the old Bridge, and began to ſpring up about 20 Feet within our Dam after a very furious Manner; on the firſt Appearance of which, I ordered the Sluices to be ſcrewed up and let the Tide in, by which we drowned the Springing, which did us very little harm; and at low Water I ſet all the Drudge and Water-men to that Corner, both without and within, and in ſhort, we took out and removed

moved from that Corner every Stone that was in our Power, and filled the Vacancies with Clay, *&c.*

Aug. 3d, The Sluices were ſcrewed down at low Water, and when there was nine Feet Flood without, the Water had roſe only thirteen Inches within.

5th, After an exceeding heavy Rain there came down a ſudden rapid Flood, and tore away many of the Ships and Lighters from the Quay, ſnapping their Moorings as a burned Pack-thread, and did them great Damage, but we were prepared for it, and kept open our Sluices, ſo that the Water then roſe as faſt within as it did without; but it did us no other damage than delay us a little, and waſh away ſome of our Clay; and after all this, the next Day we proved the Dam again, and during the whole Tide, the Water within roſe only four Inches.

EXPLANATION *of Fig.* 2. *in ſaid Plate* 13.

Wherein note, F. The Rock. G. Strata of fine ſandy Loam, which is in this Place, three Feet ſix Inches thick from the Rock, on which the rough Stone Work begins. H. The laſt Courſe of the rough Stone Work, which is laid with very large Stones carefully bedded and wrought cloſe in their Joints, to guard the thorough Foundation between the Piers from ever being diſplaced, or torn up by the Water, which is about four Feet deep at low Water. *i. i. i. Fig.* 3. Are the Ends of three Four-inch Planks that ſtretch quite a-croſs the Foundation, and on which the Sills of the Centres k. reſt. When you are doing the like Work, obſerve that between theſe running Planks and Sills, to lodge in Wedges of about 2½ Feet long, leaving about one Foot of them out, and when you come to ſtrike your Centres, deſcribe or mark them deep, that you may know how far you bring each of them out, by ſtriking each Wedge on each Side, and by that Means you will work out the Wedges by Rotation, till you have eaſed every one of them about one Inch, and then proceed after the ſame Manner, till you have eaſed them all about another Inch, and ſo proceed till you have got them all out; after which you may go on with taking them down after the uſual Manner. And this I recommend as a much

ſafer

ſafer and a more practicable Method, than Screw Wedges, which ſome have very warmly recommended.

September 28th, at 3 o'Clock in the Morning we ſet the firſt Cut-ſtone of the Land Abutment, without any Parade, which Time would not admit of.

November 1ſt, we compleatly finiſhed the North Pier, ſpringing high, and cut the ſix Inch dovetail Piles, that caſed the thorough Foundation juſt at the Surface of it, half through, ſo as we might eaſily break them off there when we pleaſed.

6th, We took up the ſtrait Beams that went a-croſs the Pit, in order to let the Carpenters put up the Centres of the North Arch.

EXPLANATION *of* PLATE XIV. *Scale* 5 *Feet* 1 *Inch.*

Fig. 1ſt, Repreſents the Plan of the Foundation of the Weſt end of the North Pier, with the rough Maſonry wrought up about the Piles, and incloſed with a Row of ſix Inch dove-tailed Piles, ſuch as you will ſee in Plate XV. Fig. 6. which were half cut off at the Surface of the thorough Foundation, and then broke off, leaving the lower Part to caſe and guard that Foundation. The other two Rows of ſquare Piles and their Sheeting, hold the Clay, which together make the inner Coffer or Pit. Fig. 2. Section of the ſame, and the Weſt End of the Pier. Wherein note, A. Rock. B. The Bottom of the rough Maſonry. C. Low-water Mark, which is eleven Feet from B.

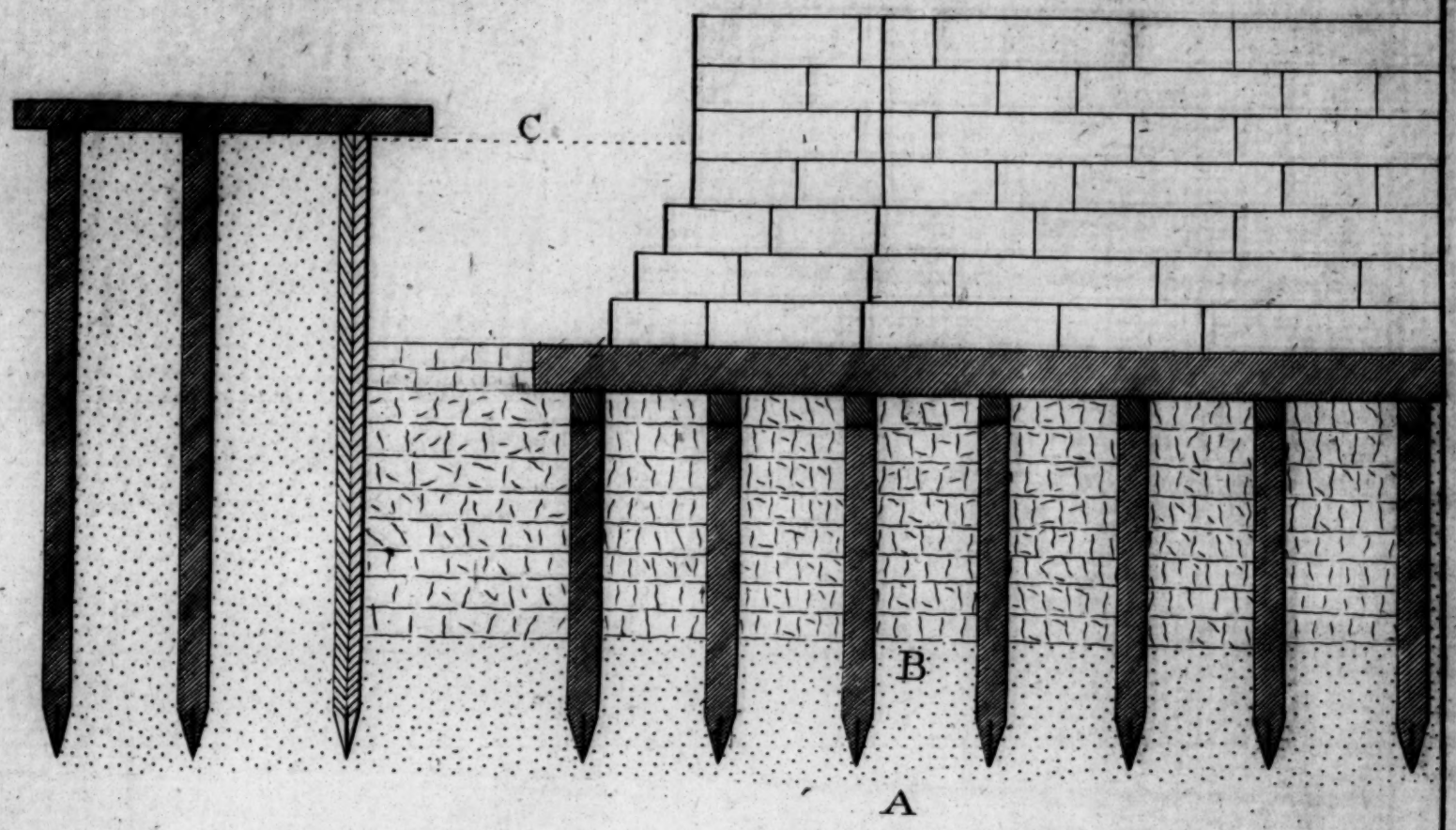
EXPLANATION *of* PLATE XV. *Scale* 5 *Feet to* 1 *Inch.*

Wherein note, *Fig.* 1. Shews the Bond of the Cut-ſtone in the bottom or firſt chained Courſe, of the Pier, with a Part of the rough Stone Foundation, covered over with large thick Stones Home to the dovetailed Piles, the Surface of which is four Feet ſix Inches beneath Low-water Mark. *Fig.* 2 and 3. ſhew the Bond of the Cut-ſtone in the other two Chain Courſes. The Chain of the firſt Courſe was near three Inches Square, and the Chains of the other two about 2 Inches Square, and all ſunk their full Depth,

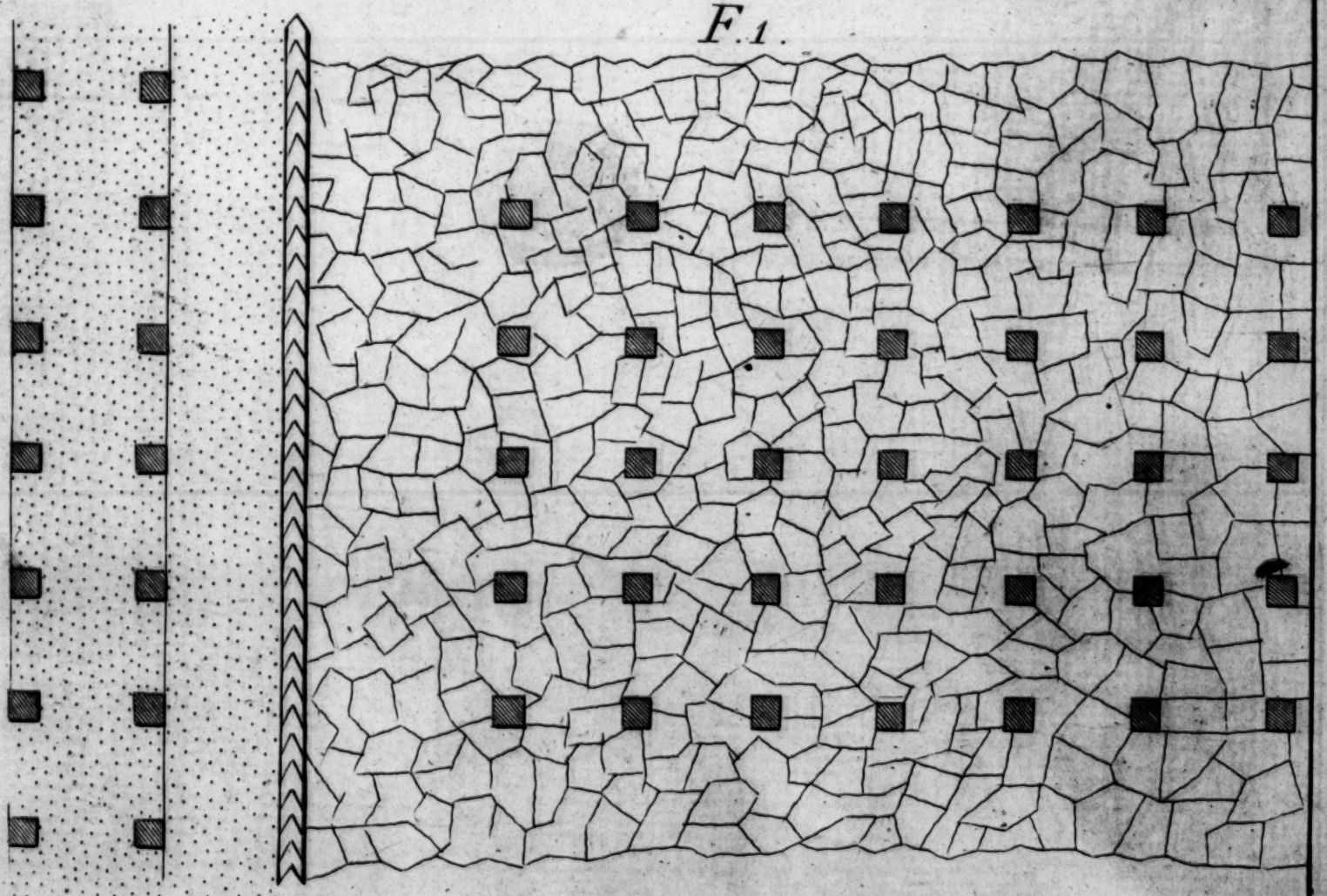
and

P. 14.

F. 2.



F. 1.



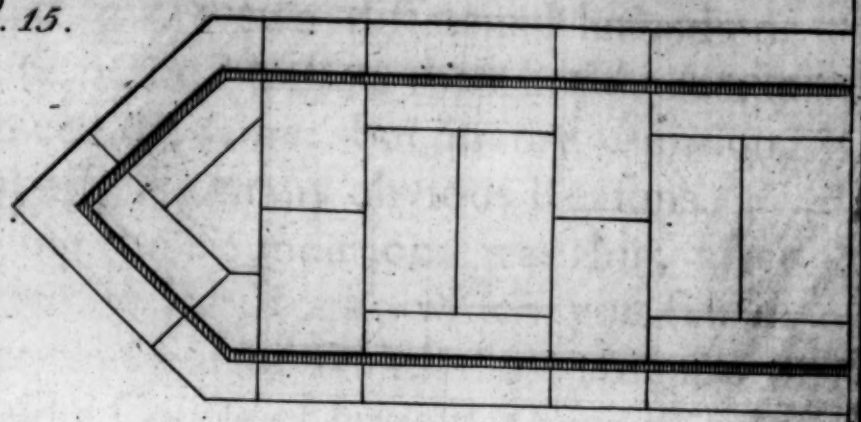


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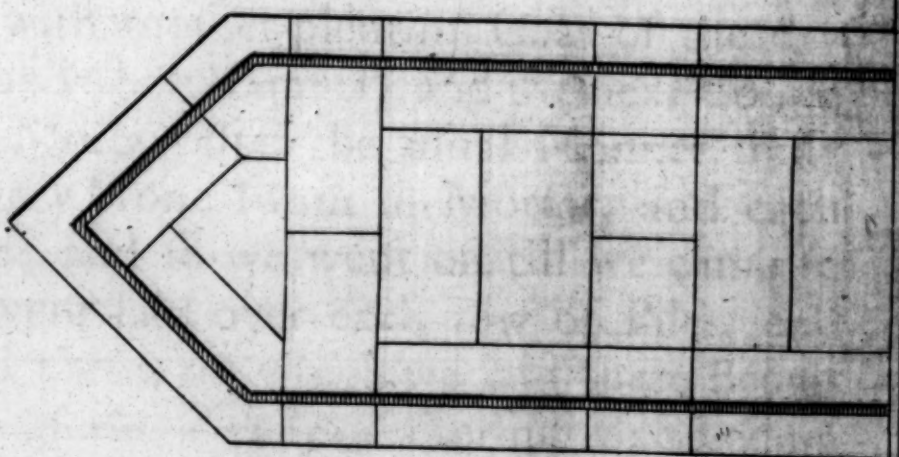
F. 4.



F. 3.



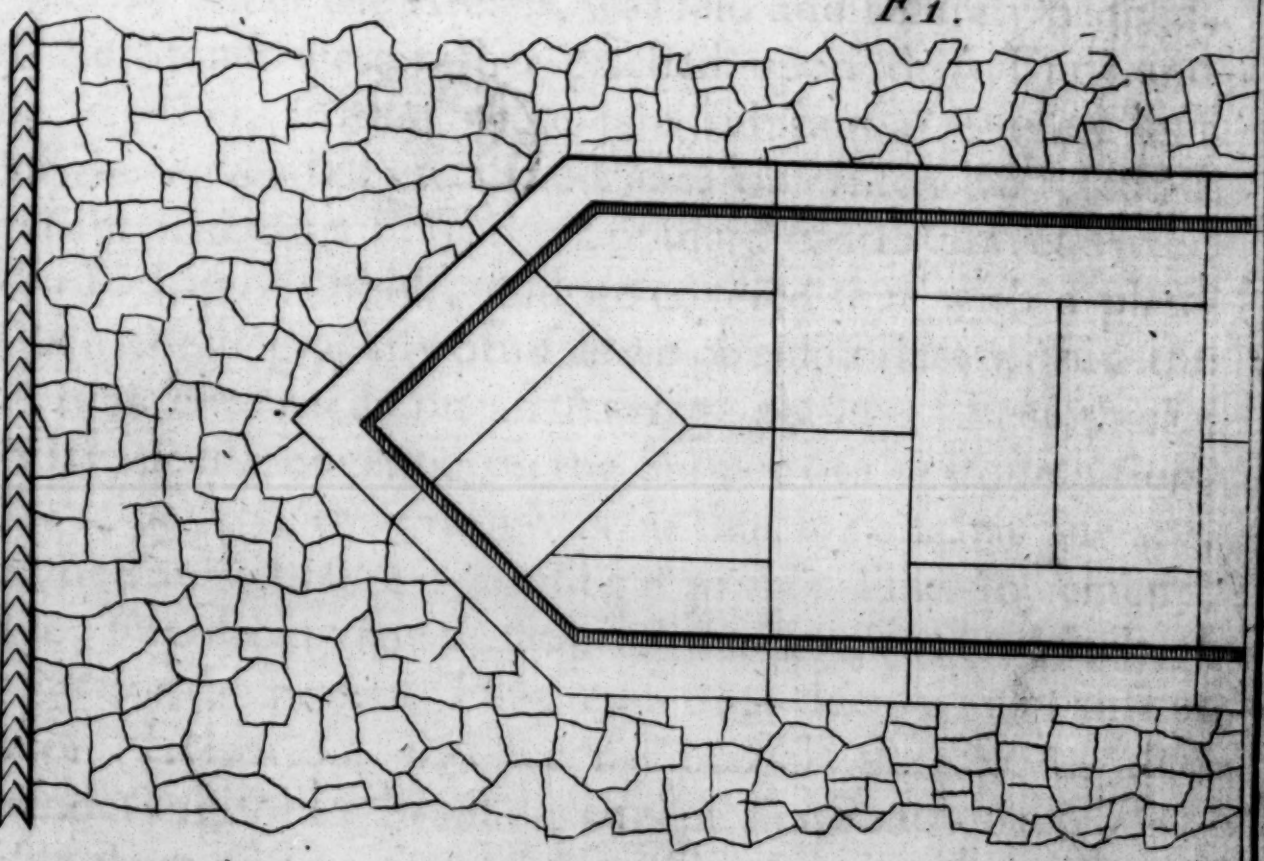
F. 2.



F. 5.



F. 1.



F. 6.





and run with Lead. Fig. 4 and 5. are two different Methods of making dovetailed Piles. Fig. 6. is the Method that *Belidor* ſeems to have made uſe of, and I followed the ſame; but in my Opinion, Fig. 4. is both the beſt and cheapeſt, for many obvious Reaſons.

The Method we took in laying the Foundation, was this; after we had drove the Oak Piles down to the Rock, which you ſaw in the laſt Plate, we ſpread a plentiful Coat of Roach-lime and ſharp Gravel over the Ground, and laid a Courſe of large flat Stones, and filled and hearted them in cloſe about the Pile for about a Foot high; then we covered that Courſe with another plentiful Coat of the dry Grout (i. e the Roach-lime and ſharp Gravel) and the next Courſe and all the reſt was laid with Mortar after the uſual Manner, only with this Difference, that every Stone ſwam in Mortar, and each Courſe was grouted as above; and ſo we went on till we came to the level for the Caps that were laid over each row of Piles, and then wrought up and levelled them, on which we laid three Beams ſtretching the whole Length of the Pier from Sterling to Sterling, and filled up about them with the Maſonry; but the thorough Foundation that lay under the Arches, was laid and ſecurely bedded, and many of the Stones were rather pitched upon their Ends and wrought cloſe together, ſo that there is a ſubſtantial Stone Floor for the Bed of the River between the Piers, on which we ſpread a Courſe or Stratum of about a Foot thick of ſharp coarſe Gravel mixed with new and old Lime-rubbiſh, and we covered that with a plentiful Bed of ſuch coarſe gravelly Stuff as we could collect within the Dams, which together, made on an Average about 2½ Feet thick; my reaſon for laying this covering on the Surface of the Foundation, was principally to preſerve the green Mortar that lay on that Surface, from being waſhed away before it would get proper Time to cement; and as I had 4½ Feet from that Surface to the Low-water Mark, I concluded, that for the preſent Time two Feet deep would anſwer the Purpoſes of Navigation, and we finiſhed all the reſt of that thorough Foundation in like Manner, except the South Arch.

I am ſenſible there was no ſort of Neceſſity for piling this Foundation, as there was ſuch a Depth of Maſonry under the Piers, however, as it could not be ſo ſtrong as on the South Side, where

they were built on, or very near the Rock, I thought it adviſable (as we had plenty of Piles) rather to err on the ſafe Side.

CHAP. IX.

Concerning different Methods of centering, for large Stone Bridges, and a Continuation of the Abſtract of our Diary.

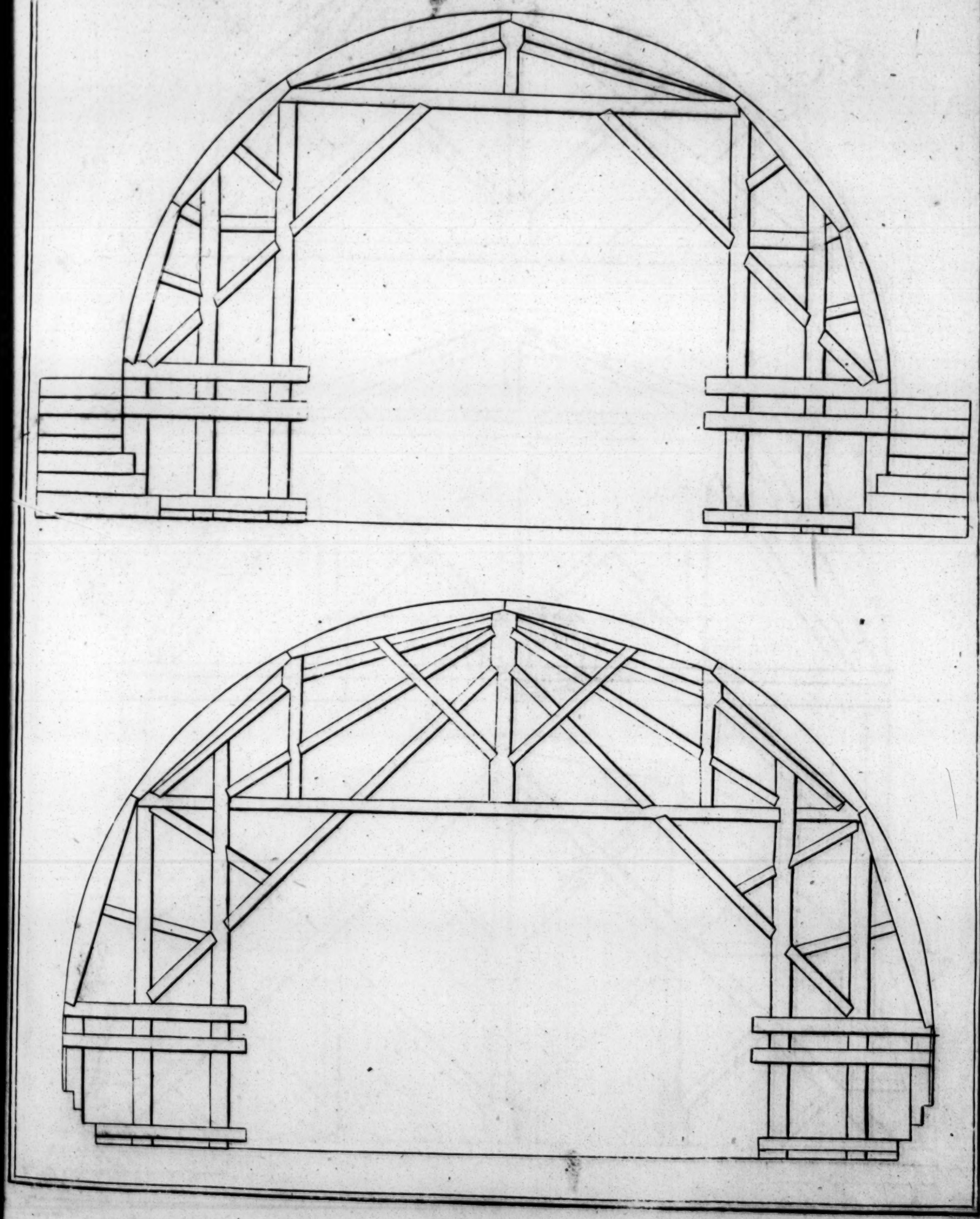
THAT Part of a Centre, which I ſhewed you in Plate XIII. Fig. 3. is ſufficient for our preſent Purpoſe; but ſuch Centres are only proper where there is ſuch a Foundation, but in other reſpects it would not anſwer.

In Plate XVI. (Scale 8 Feet 1 Inch) you have two other Methods of centering with Crown Beams, the Prick-poſts reſting on 4 Inch Plank ſtretched parallel to the Piers upon the thorough Foundations, as above-mentioned; but in Caſe you have not ſuch a Foundation, your whole Dependance muſt be upon your Piers, as in Plate XVII. (by the ſame Scale) in which you have three different Deſigns; and notwithſtanding they are drawn for 36, 41 and 46 Feet Spans, yet if you conſider every Thing in Proportion, they may very well anſwer for double thoſe Spans: And I apprehend, that Fig. 2. ſhews you a very ſafe Way to ſupport them, *viz.* In the three projecting Courſes of your Piers, make your upper ſet off about 10 or 12 Inches, more or leſs, according to the ſize of your Arches, as at *a. a.* and on thoſe ſet-off's ſtretch your Plates, and on them reſt your Spur-braces as in the Draft, never forgetting to put in the Wedges before-mentioned, for in Truth, no Centres ought to be put up without them; for by eaſing your Centers gently, every Part of the Arch has Time to come to its proper bearing, and many an Arch as well as Vault, has been diſlocated by ſtriking them abruptly.

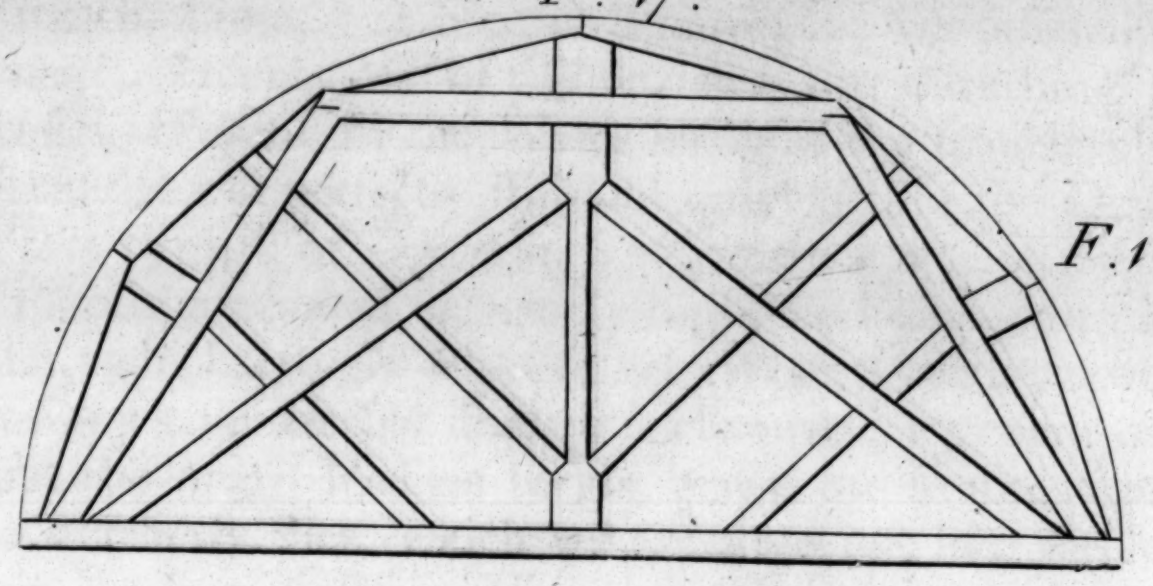
December 4th, There came down a terrible Flood, but we expected it from the heavy Rains we had, and prepared for it. The firſt high Water afterwards roſe to 12 Feet 6 Inches, and every high Water afterwards roſe to 12 or 13 Feet for ſix ſucceſſive Days, and even at low Water the Floods kept up to 8 or 9 Feet, during

all

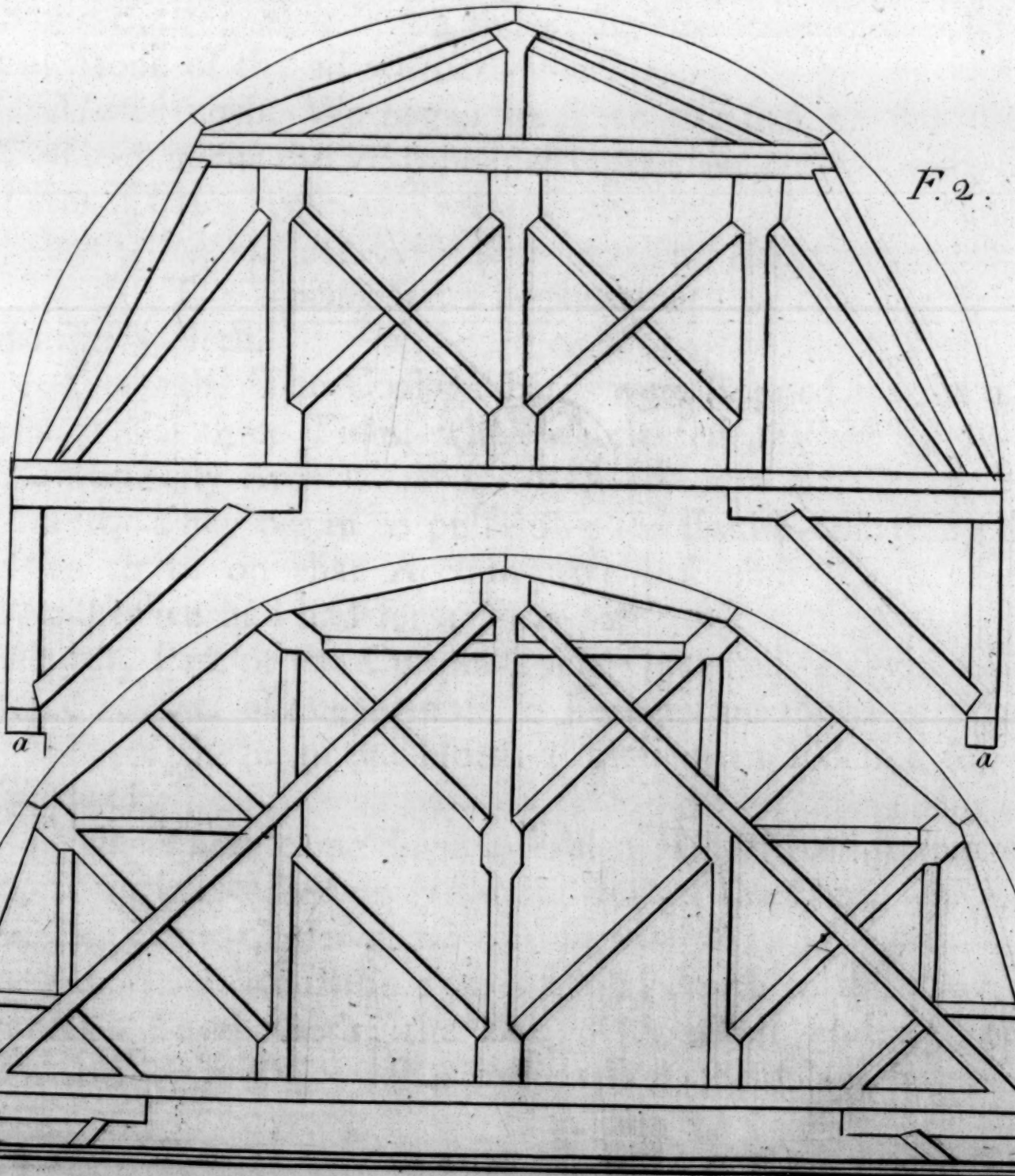
Pl. 16.







F. 1.



F. 2.

F. 3.



all which Time, our Sluices being open, we ſuffered little or no Damage, except loſs of Time, and the diſturbing our Stages, Utenſils, *&c.* for all the Water being at the ſame level within and without, it was perfectly ſtill and quiet within the Dam.

From the 4th of *December* 1753, to the 23d of *February* 1754, the Floods continued extremely high, and often to 13 Feet at high Water, which greatly retarded our Work; but otherwiſe, did not do us any conſiderable damage: However, we were now enabled to put the rough Maſons to get ready the Foundation of the ſecond northerly Pier, which we executed juſt like the former; and within the Space of four Nights and Days, we had it ready for the Stone-cutters, that is, on the 27th, the Stone-cutters laid the firſt cut Stone of the 2d northerly Pier.

March 19th, We began to drive the firſt of the Piles of the Coffer-dam for the 2d principal Operation on the South Side. *See Plate* XVIII. *Scale* 40 *Feet* 1 *Inch.*

29th, Second northerly Pier ſpringing high.

30th, The Stone-cutters began to lay the firſt Courſe of the 2d northerly Arch.

April 8th, The Coal-gabbards were ſtopped for the firſt Time, and miſſed three Tides, when we cleared a Way for them under the northerly Arch.

22d, They began to pull down the Exciſe-office; by the delays given to us on that Account, we loſt eight Days of the fineſt Weather we had had for a Year paſt.

25th, Part of the Cuſtom-houſe Quay fell, by which we diſcovered another old Quay-wall, 6 Feet within that.

May 23d, Both the North Arches open and free for the Coal Gabbards.

25th, There came down a ſudden rapid Flood from the Mountains, which waſhed away a great deal of the Clay, which we were putting in the Coffer-dam.

June 5th, From the 25th of laſt Month to this Day, we had conſtant Land-floods; the Ebbs ſeldom fell under 3 ½ or 4 Feet. Theſe Floods deſtroyed a vaſt deal of the Clay, but with great

Difficulty we got the Current turned entirely into the North Channel, to its full Depth.

14th and 15th, The Land-floods at Low-water were from 8 to 9 Feet.

25th, This and former Days we had great Labour in taking up the Ridge of looſe Stones, which lay in a direct Line quite a-croſs the River below Bridge, as before-mentioned; but dear bought Experience had taught us to ſpare neither Time nor Coſt to get thoſe dreadful Peſts removed from under the Dike.

July 27th, Theſe ſix Days we had exceeding rapid Mountain Floods; high Water generally about 11 Feet.

Auguſt 4th, We finiſhed the rough Stone Foundation of the South Pier of the middle Arch.

5th, The Stone-cutters began to ſet the ſame Pier.

12th, In drudging for the South-eaſt corner of the Dam, we met with very large Cakes of the petrified Sand, that the Floods had carried down into the deep Water, which they were forced to break to ſmaller Pieces, by driving well-ſhod Piles into them.

28th, We ſtopped all the Pumps, as we had no further Occaſion for them.

From the 20th to the 28th of *September*, we were obliged to ſtop the Carriages, from going along *Eſſex-quay*, on account of our ſinking for the South Abutment, in doing which, we raiſed Part of the Foundation of *Newman's Tower*, which had been very judiciouſly laid on the ſolid Rock, and we were alſo obliged to quarry in ſome Places two or three Feet deep of the Rock, to bring it to a proper level, and omitted two Courſes of the Cut-ſtone of that Abutment, as the third of the projecting Courſes were laid upon the ſolid Rock.

October 7th, The Abutment finiſhed, ſpringing high, and the ſame Day we began to lay the Foundation of the South-quay Walls.

CHAP.

CHAP. X.

The proper Method of building Quay Walls, and a Continuation of the Abſtract of our Diary.

I SHOULD think myſelf very reprehenſible, did I forbear to diſcover the true Proportion of *Quay Walls*, which I was taught by an eminent and worthy Gentleman, Major *Marcell*; but previous to the Proportions, there are other Things to be conſidered, the principal of which is, the Nature of the Ground on which it is to be built, and to be ſure, if it be not ſtrong enough, that you make it ſo by piling, and that the Foundation of the Wall be laid of a ſufficient Depth, the front Courſe of large and long Headers, that will admit of making a good ſet-off; all which being duly conſidered, you are then to calculate how far that Foundation is to project.

The Major's rule is this, "That the out-ſide of a Quay Wall, ought to batter one ſixth Part of the Height of it." And leſt you ſhould not clearly underſtand this moſt excellent rule, I ſhall perhaps make it the more intelligible, by giving you an Inſtance of a Wall, that is to be twelve Feet high from the Surface, or level of the Foundation before-mentioned.

Every Foot your Wall riſes muſt batter two Inches, then your 12 Feet high muſt batter 24 Inches, and to this add 18 Inches for the Thickneſs of your Parapet, which will make three Feet ſix Inches, for the Bottom of the Wall that ſtands on the Foundation, and allowing at leaſt three Inches for the ſet-off, your Foundation muſt be three Feet nine Inches broad; obſerving that the back of the Wall is to be carried up perpendicularly, and the Stones laid firm, and after a Workman-like Manner againſt the Bank, for if you only build the out-ſide fair, and fill the back and inſide careleſsly, or perhaps, with a ſcanty Allowance of Mortar, that Wall could not ſtand long, let the batter be what it would.

In order to carry on this Wall properly, you are to make a Plumb-Rule fit for the Purpoſe, with one ſide of it Plumb, and the other

Side

Side to fit the battering Side; but if you are carrying on a new Quay Wall of any conſiderable Length, you ought to work by a battering Frame, always obſerving, that the top of your Frame (which we ſuppoſe to be 18 Inches broad) be exactly level to the level of the Bank, otherwiſe, you will find you will be either too broad or too narrow when you come to the Surface of the Bank; and indeed, all theſe rules ought to be obſerved in building a Wall againſt any other Bank. For ſuppoſe you build a Plumb Wall againſt any Bank, which I have generally ſeen practiſed, the Rain or Wet is continually carrying down a Quantity of looſe Particles, which become a Wedge between the top of the Wall and the Bank; and like taking a Sword in the feeble of the Point, the further it goes the more Power it will gain, and thereby increaſe its own Purchaſe, till it at Length totally demoliſhes it.

November 1ſt, We began to put up the Centres for the two ſoutherly Arches, and prepared to do the ſame for the Centre Arch.

January 10th, 1755, The Haunches of the two northerly Arches being compleated, we made a ſafe and commodious Foot-way to the Dike, which we railed in, and which proved of great Advantage both to the Public and our Work.

March 5th, The ſecond South Arch was finiſhed, and we began to build the croſs Walls from the Crowns of the Arches, in order to make the Carriage Way.

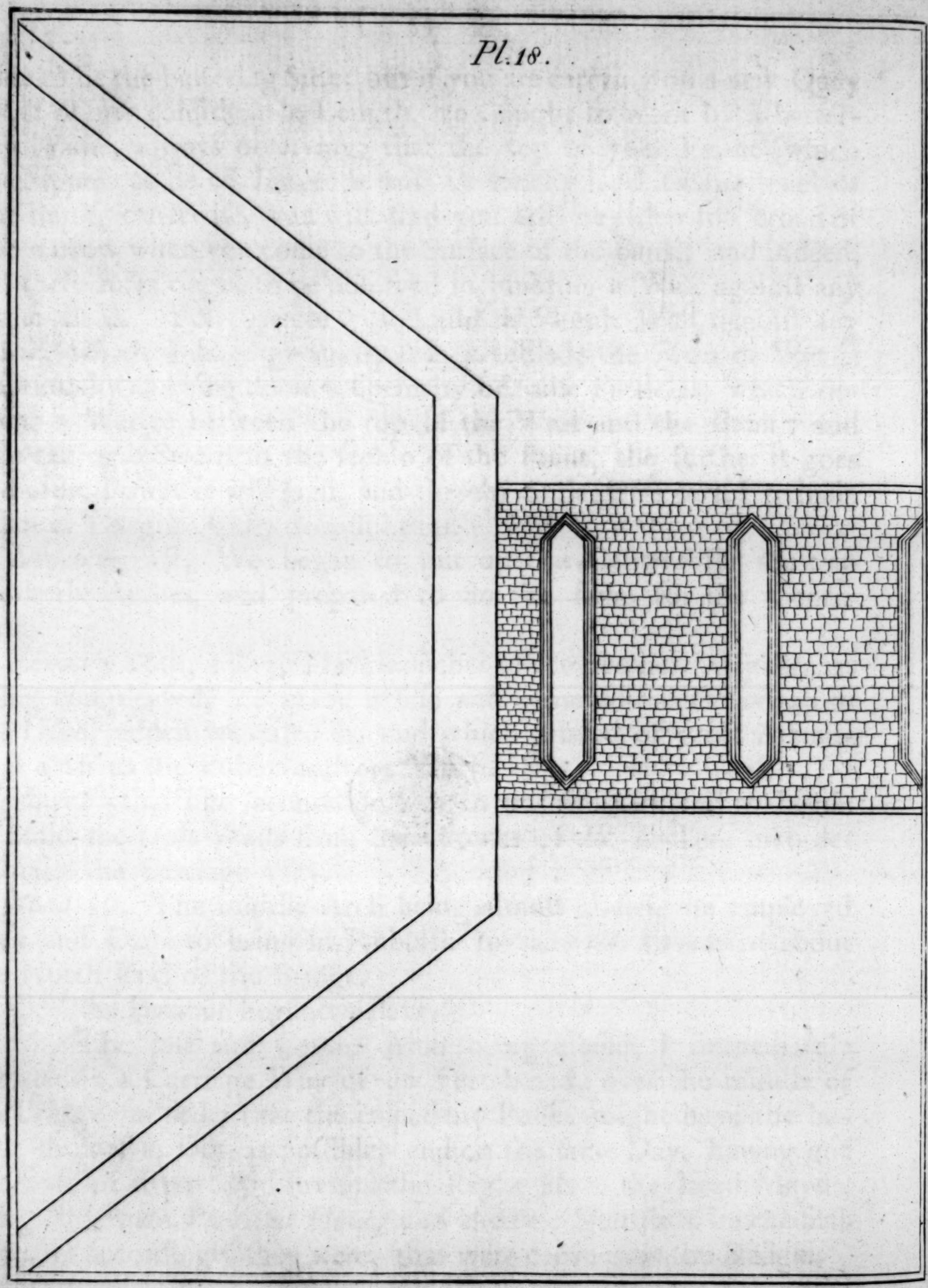
April 1ſt, The middle Arch being almoſt cloſed, we employed Men and Carts to bring in Rubbiſh to raiſe the Pavement about the North End of the Bridge.

3d, The Paviour began to Pave.

8th, The laſt and Center Arch being cloſed, I immediately boarded in a Carriage Way of 20 Feet broad, over the middle of the Bridge, in order that the impatient Public might have the benefit thereof as ſoon as poſſible; and on the ſame Day, having got one Side of it paved, I invited the Right Hon. the Lord Mayor, being Alderman *Percival Hunt*, and the two Sheriffs to be the firſt three, as accordingly they were, that were drove over the Bridge.

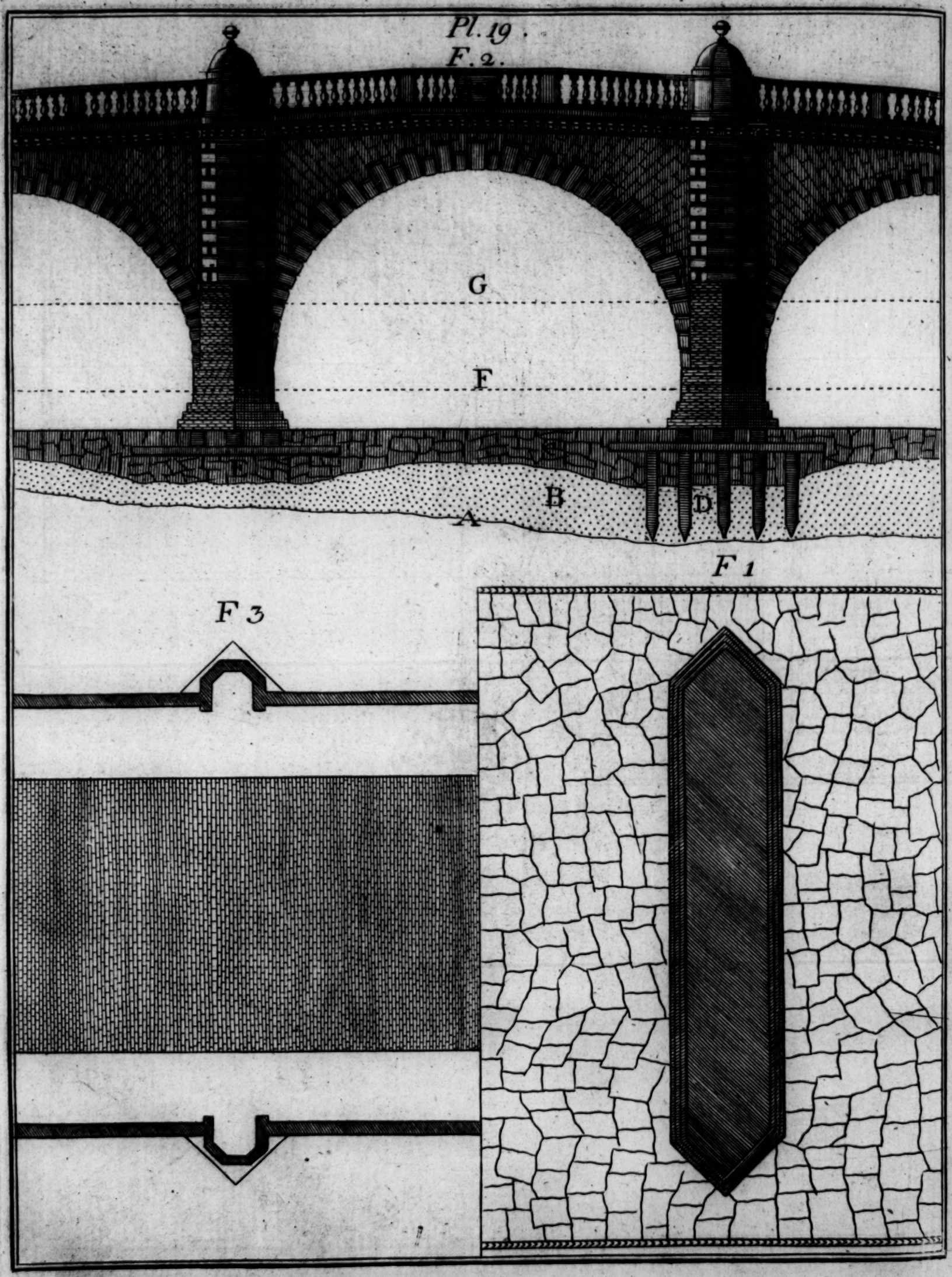
10th,

Pl. 18.



Pl. 19.

F. 2.



F 1

F 3

10th, The Bridge was left open for the uſe of the Public in general, which made two Years and eighty Days, ſince the Day on which they were deprived of the uſe of the old Bridge, which was *January* 19th, 1753.

EXPLANATION *of* PLATE XVIII. *Scale* 40 *Feet to* 1 *Inch.*

Shews you the ſecond principal Operation with the thorough Foundation, Piers and Part of the Abutment to the Northward, and the new Coffer-dam on the South, on which I need not enlarge any further.

EXPLANATION *of* PLATE XIX. *Scale* 16 *Feet to* 1 *Inch.*

Fig. 1. Exhibits the Plan of the northerly Pier of the Center Arch, ſtanding on the thorough Foundation, which is laid over with large Stones, Hough and Ham, and ſome pitched upon their Ends, and all of them wrought cloſe and carefully bedded in Mortar, and the whole covered with a plentiful Coat of dry Grout, and that covered with a thick Bed of ſharp Gravel, to preſerve the Mortar till it Cements; on the Extremities of which, you ſee Part of the two Rows of dovetailed Piles which are drove down to the Rock, and cut off at the Surface of the Foundation, which is four Feet and a half under the Low-water Mark, as mentioned before in the Explanations of Plates XIII and XIV.

Fig. 2. Shews the Center Arch, and half of each of the next adjoining Arches, compleatly finiſhed, wherein note, A. The Rock in that Part of the River. B. Part of the natural Bed of the River. C. Thorough Foundation quite a-croſs the River, built as above and before-mentioned. D. Five Rows of Oak Piles drove down to the Rock, with a Grating of Timber on them, and wrought into the Maſonry. E. The like Grating of Timber under the ſoutherly Pier. F. Low, and G. High-water Marks.

Fig. 3. This Figure repreſents Part of the Superſtructure, which extends 51 Feet from out to out of the Plinth of the Balluſtrade. The Foot-ways are 8 Feet each, and the Carriage-way 31 Feet.

This,

This, according to my original Plan, was to be paved with Fire-ſtone, in 5 or 6 Inch Courſes, each Courſe to be ſcabbled or rough punched at about 1 Inch or 1½ Inch convex, ſo that the Feet of the draught Horſes might take a firm hold of them; and theſe Courſes were to be from 18 Inches to about 2 Feet in Depth, and ſet with good cloſe Joints in ſwimming Beds of good Mortar, and for this purpoſe I took Care to leave a proper Depth on the crown of the Center Arch. And now I hope that what I have offered concerning this Bridge fully expreſſes every Thing neceſſary for you to know concerning it.

Tho' the intended Brevity of this Work obliges me to be as conciſe as poſſible, yet I think, I ought to embrace this Opportunity to relate a particular Incident that lately happened at this Bridge; but I muſt firſt recommend it to you to recollect the covering I had laid on this thorough Foundation between the Piers, as mentioned in the latter End of the explanatory Notes on Plate XV.

This laſt Winter has been very remarkable for exceeding high Land-floods in this River, but particularly one that came ſuddenly down from the Mountains on the laſt Day of *January*, 1775, with ſuch Violence, that it broke the Moorings, and carried off eight Gabbards from the *Coal-quay*; five of them were ſtopped for ſome Days by *Eſſex-bridge*, and three of them carried directly down the River; one of theſe five lodged againſt the Sterlings of the middle Piers, and the Flood continuing very violent ten ſucceeding Days, it was quite impracticable to get her off.

As my young Reader may, perhaps, not be acquainted with the natural Effects of ſuch an Obſtruction, it is neceſſary to obſerve, that Shoals or Sharps in navigable Rivers, have frequently been deepened and carried off by lodging loaded Gabbards quite a-croſs them, becauſe they ſtop the Current at the Surface, and preſs powerfully on the Water at the Bottom, which conſequently encreaſe the Strength and Velocity thereof, and ſo break up and carry off the Bed of the River in ſuch Places.

But I ſhall give a recent and more familiar Inſtance: About ten Years ago, a rapid Land-flood broke the Moorings of a Raft of Timber at the Barrack-ſlip, and carried it down to *Queen's-bridge*, where

where it unluckily lodged quite a-croſs the middle Arch. The Piers of this Bridge were built on the Surface of the Bed of the River, as moſt of the former Bridges were. This Raft of Timber obſtructing the Current of the Surface, in like Manner increaſed the Power of it at the bottom, and within the Space of a few Hours totally demoliſhed the Bridge. But to proceed.

During the ten Days that this Gabbard lodged againſt the Sterlings of the middle Piers, I felt not the leaſt Perturbation, but on the contrary I found my Heart exult with inexpreſſible Pleaſure, being thoroughly convinced, that if all the Arches were ſtopped up in like Manner for many ſucceſſive Years, that they would have no more effect on that Foundation than if it had been a ſolid Rock: However, after the Flood had fallen, Curioſity induced me to examine the Effects of it, and I really was ſurprized to find, that even the firſt Foot Stratum of the covering which we laid over the Foundation was not in the leaſt Degree moleſted. Indeed, the upper Parts of the covering were by that and former Floods moſtly waſhed away, but not ſtripped of it intirely in any Place, and even if it was all waſhed away, yet the Mortar on the Surface of it is by this Time ſo effectually cemented, that the Current paſſing over it could not make the leaſt Impreſſion on it; and the red Firr dovetailed Piles that caſe and incloſe it down to the Rock (being in Water) will moſt aſſuredly laſt firm and ſound for numerous Generations to come; and in the Interval, the Maſonry will in reaſonable Time cement to ſuch a Degree, as if the Mortar and Grout of the whole were actually petrified, and even ſo, as to put it out of the Power of Time to deſtroy it.

For theſe Reaſons I moſt earneſtly recommend it to you, to do all in your Power to make thorough Foundations in like Manner, quite a-croſs ſuch Rivers as you may happen to be employed in, that you may enjoy the like tranquil State of Mind, during the remainder of your Life, which I experienced when I ſaw the Gabbard lie a-croſs that Arch.

SECT. I.

Concerning other neceſſary Matters relative to the building of Stone-Bridges.

I HAVE now cheerfully communicated a ſhort account of our Proceedings at *Eſſex-Bridge*, and mentioned every Thing I thought materially neceſſary for the young Student in the Art of Bridge-building to know, of which, the principal is the Uſe and Conſtruction of Coffer-dams; and I am ſure he may by this Time form a clear Notion of their Utility in Works of this Nature, nor can I conceive the leaſt Idea of any other Way to lay ſuch ſubſtantial and thorough Foundations as may be done by their Means.

I muſt indeed, confeſs, that the building of the Bridge, was attended with a great deal of Labour Night and Day, for upwards of two Years and a half ſucceſſively, but that was chiefly owing to the Foulneſs and Looſeneſs of the Ground, which would not have been the Caſe, had we been working on clean and freſh Maiden Ground, for on ſuch, there would be but few Difficulties to encounter with; and therefore, to prevent your being diſcouraged, I muſt remind you again, that Mr. *Labely* was quite miſtaken in his Calculation (mentioned in Page 31,) for notwithſtanding the exceeding great Roughneſs of our Ground, the Rapidity of the River, and the very great Depth we were obliged to ſink, and that the whole Circuit of of our Dams was much larger than what he would want for one of his Piers, yet, after we had got our Dams ſtaunched, there did not ſoak for many Tides ſucceſſively, (excluſive of the ſubterraneous Water, mentioned in the 7th Chapter) a ſingle Hogſhead of Water into our Pit, notwithſtanding its exceeding great Depth; but it is not my Intention to leſſen the Reputation which that great Artiſt has juſtly eſtabliſhed, although to prevent your being diſcouraged from ſuch undertakings by what he has advanced, and for your further Improvement, I believe, without running the hazard of Cenſure, I might venture to make ſome further remarks

upon it, but I ſhall leave that to your own Sagacity, by your comparing what he has *ſaid*, to what we actually *performed*.

When you come to Work upon freſh Maiden Ground (as I mentioned above) you will find no ſuch Difficulties, but will have ſure ready Work, even at the Depth we went to at the North End, and probably on ſuch freſh Ground, you need not ſink much deeper than about three, four or five Feet under the Bed of the River, unleſs you intend to lay a thorough Foundation; but if you do not, that will be fully ſufficient, provided you drive down ſuch Piles as I have recommended in Plate 15, Fig. 4, all round your Foundation, till they get into firm Ground.

In ſhallow, freſh Water Rivers, the Difficulties and Expences attending this Manner of working, are quite inconſiderable; but you muſt always obſerve, that let the Water be what Depth it will, you proportion the Strength of your Dams to the Depth that you are to ſink from the Surface of the high Water. In ſuch Rivers as are under ſix Feet deep, you may make your Dams very ſlight, excepting in ſuch Rivers as are ſubject to ſudden Mountain Floods: Recollect what *L. B. Alberti* has left us (ſee Page 9) which are, I think, the fulleſt and cleareſt Directions I have met with, and according to the ſame Manner which he there directs, I adviſe you to make your Dams in ſuch Rivers as are under this Depth; but in ſuch Water as is only about a Yard deep, one row of Stakes may anſwer your purpoſe, and in ſhallower Water, Sods may prove ſufficient; but be well prepared and extremely expeditious, leſt a Land-flood ſhould come upon you, yet, even if it did, the Expence would be but inconſiderable.

There have been ſeveral Methods practiſed by illiterate Country Maſons, who have built good rough Stone Bridges over ſuch ſhallow Rivers as theſe, and ſome of them in much deeper Water. I ſhall mention a few of their Methods; ſuch as, 1ſt, *Keſh-work*, that is, a kind of large Baſkets, made of the Boughs and Branches of Trees, about the ſize of four or five Feet Square; theſe they ſink in rows, by throwing Stones promiſcuouſly into them till they ground, and then filling them up till the Water is about Knee-deep, whereon they lay Timber a-croſs, and ſo begin to build their Piers,

banking the Kiſhes all round with other Stones and hard Stuff thrown in, in like Manner. 2d, *Keeve-work*, that is, making large Veſſels of red Deal Boards, hooped both with Iron and ſtrong Oak Hoops, which they fill and ſink in like Manner, filling the Vacancies between the Circles, and banking them round with the like rude Stones, *&c.* 3d, *Cheſt-work*, i. e. making large Cheſts of 5 or 6 Feet Square of red Fir Plank, dovetailed and claſped with Iron at the Angles, and theſe they alſo fill and bank in like Manner, which is generally among ſuch Workmen deemed a good Method, becauſe they lie ſo very contiguous to one another, and are very durable. 4th, *Caſe-work*, which is of the ſame Nature, only much larger and ſtronger, ſome of them being 12 or 15 Feet Square, and filled and banked after the ſame Manner. The 5th, is generally made uſe of by eminent Workmen in much larger Works. They call it *Caſe-work*, the *French* Caisson. They are made of large Timber, proportionable to the intended Uſe, and in Bridge-building, will admit of the whole Pier being built within them. Their bottom is a Grating of ſtrong Timber, and their Sides of ſquare Scantling and thick Planks, which are to be diſengaged from the bottom, when the Pier is built within them to above the low Water mark, and then they are to be made uſe of for the next Pier. They are made perfectly ſtaunch, and a Pit is drudged in the Bed of the River, as deep as they think ſufficient, wherein the Weight of the Work ſinks theſe Caſes. All which Methods and ſeveral others, I moſt minutely conſidered before I deſigned *Eſſex-bridge*, and found that none of them would anſwer my purpoſe; but having carefully preſerved my Remarks, Plans and Sketches on thoſe various Methods, and at innumerable Times ſince digeſted them moſt accurately, and alſo improved the Obſervations I made on the Petrifactions before mentioned; I apprehended and endeavoured to contrive ſome others, which I preſume among us, may be called *new* Methods, which probably may prove more effectual in moſt Caſes than any of them, which I have deſigned to anſwer either in freſh or ſalt Water of very conſiderable Depths, and which I ſhall reſerve for the Subject of the ſecond Part of this little Work.

I am

I am fully convinced, that the Society of Artiſts that have been lately eſtabliſhed in *Dublin*, through the generous Aſſiſtance of the *Dublin Society*, has already proved of infinite Service in this Kingdom; and that ſuch a noble Eſtabliſhment cannot fail in Time, to produce very ingenious and uſeful Men among us, many having already began to ſhine forth in different Branches of Science, and particularly in Architecture. This, I think, inconteſtibly proves that the People of this Country, have as good natural Abilities as thoſe of any other, and were they to meet with equal Encouragement, there can be no Doubt, but they would carry the Sciences and the Arts to as great a Perfection; Encouragement being the kindly Sunſhine, which expands the budding Flowers, and makes them produce much good Fruit.

The Guild of Merchants, as an Encouragement to that Society, moſt generouſly paid 50 *l.* for the beſt, 30 *l.* for the ſecond beſt, and 20 *l.* for the third beſt Deſign for the *Royal Exchange:* And the Corporation of this City followed their laudable Example, in procuring Deſigns for the *Blue-coat Hoſpital.* And there is no Doubt but when *Ormond-bridge* has fallen down, but they will continue to exerciſe the ſame moſt uſeful Generoſity, and perhaps, much enlarge thoſe Sums, as the Nature of that extraordinary kind of Work, and the preſcribing proper and effectual Methods for laying the Foundations in particular, require a great deal of Labour, and juſtly merit a very liberal Compenſation.

In Hopes that many young Students in Architecture, may not only become Candidates, but actually merit the higheſt Prize, I intend freely and fully to furniſh them with proper Inſtructions for that purpoſe, to the beſt of my Knowledge, but chiefly with reſpect to the Foundation, and the principal Lines ſuitable to that Bridge; but in order to exerciſe their own Ingenuity, I ſhall leave the Decorations to themſelves.

I have ſhewn what a loſs I was at, and what infinite Trouble I had to find out and procure effectual Methods to lay the Foundation of *Eſſex-bridge.* I have given a ſuccinct Narrative of the whole of my Proceedings in that Work. I alſo ſet forth the good Fortune I had in getting Colonel *Belidor*'s Method of making

Coffer-

Coffer-dams, in the very critical Time I wanted it, for I had every Thing elſe to invent, to contrive and to reduce into order. The whole of theſe ſeveral Particulars you have now before you, and on a thorough grounded Knowledge I aſſure you, that the various Circumſtances relative to the re-building of *Eſſex-bridge* that is done, and *Ormond-bridge* that muſt ſoon be done, are exactly ſimilar to one another, excepting, indeed, that the latter will be much leſs in ſize, and not near ſo troubleſome nor expenſive as the former; but I am very certain, there is no other Method to accompliſh it than that by which I compleated the other. The whole of what relates to the firſt, and all that is neceſſary for the latter, you have alſo now before you ready at Hand, without giving you the leaſt Trouble to contrive or invent any Thing. And I hope my young Countrymen will now exert themſelves, and uſe their utmoſt Endeavours to make themſelves Maſters of the Art of Bridge-building, and not lay the Corporation of the City, or other Gentlemen under a Neceſſity of procuring Artiſts from other Countries, when they have, or may have as fit Perſons for their Purpoſes at home.

CHAP. XI.

Concerning ORMOND-BRIDGE, *with the Soundings and Borings adjacent, and Remarks on the Bed of the River.*

IN the Year 1682, Sir *Humphrey Jervis* built a Bridge of Timber in this Place, which ſtood but two Years, which was, probably, partly owing to the injudicious Conſtruction of it, or more probably to the intolerable ſoftneſs of the Ground it was built upon; but be that as it may, in the Year 1684, the Corporation of the City began to build the preſent Bridge. See Plate XX. Scale 20 Feet, 1 Inch.

In *April* 1752, this Bridge was in the utmoſt Danger of ſharing the ſame Fate that *Eſſex-bridge* had ſo lately met with; on which my Brother *John* and I were ordered to go and examine it, which accordingly we did, and we found that the South Pier at A, had greatly failed: The Bed of the River on which it ſtood was waſhed away,

N°.	Feet.	Inches.	
3	9	11	To the Bed.
	6	3	Harder and coarſer Sand.
	7	5	Soft blue Clay or Loam.
	23	7	Rock.
4	15	0	To the Bed.
	6	5	Coarſe, gravelly Sand.
	8	0	Soft blue Clay or Loam.
	29	5	Rock.
5	0	3	To the Bed, (North Side)
	11	6	Soft blue, ſandy Clay or Loam.
	21	9	Rock.
6	9	11	To the Bed.
	9	7	Exceeding ſoft, ſandy Clay or Loam.
	19	6	Rock.
7	10	2	To the Bed.
	9	7	Exceeding ſoft, blue Clay, or rather Mud.
	19	9	Rock.
8	11	4	To the Bed.
	10	0	Very ſoft blue Clay, or rather Mud.
	21	4	Rock.
9	10	1	To the Bed.
	8	2	Exceeding ſoft blue Clay, or Mud.
	18	3	Rock.
10	9	2	To the Bed.
	8	2	Exceeding ſoft Loam, or Mud.
	17	4	Rock.
11	10	0	To the Bed.
	8	7	Exceeding ſoft Mud. *N. B.* The Men found this ſo ſoft, that they thruſt down the Rods in a Minute without boring, and they believed they could do the ſame with a ten Foot Rod, after they were through the upper Cruſt of Sand and Rubbiſh.
	18	7	Rock.

N°.	Feet.	Inches.	
12	11	6	To the Bed.
	10	2	More ſtiff and coarſer.
	21	8	Rock.

The dotted Line which incloſes the South Pier, is the outward bounds of the Coffer-dam, which we made to keep off the Water, till we under-pinned that Weſt End of it, where we found that there was nothing ſupporting the upper Work, but the Bond of the Stones, and the Strength of the Mortar as before-mentioned, for that Pier had not a Frame of Wood planked in the bottom, under nor round it, as the Piers of *Eſſex-bridge* had, but the bottom Courſe of it was laid on the naked Bed of the River, as I believe all the reſt of the Piers are. Some of them have ſunk to the Eaſtward, and ſome of them, but particularly the North Pier, to the Weſtward, one Foot nine Inches at B. more than at C. and greatly diſlocated that Arch, which I believe has been rebuilt, for by the Courſes of the Stones in the Piers, it is evident that no Arch could poſſibly ſtand, when one End of the Pier had ſettled ſo much more than the other, and conſidering all theſe Borings together, it is ſomewhat ſurprizing it has ſtood ſo long.

The large Dotts in the dotted Line, were taken in order to know the different Depths of the Water, whence to calculate the Length of the Piles for the Dam; but they alſo are of ſome uſe now, in giving us the Depths of the Water from high Water mark, in thoſe ſeveral Places, *viz.*

N°.	Depth.		N°.	Depth.	
	Feet.	Inches.		Feet.	Inches.
13	5	3	19	11	3
14	5	9	20	12	1
15	8	5	21	20	0
16	11	9	22	20	0
17	12	9	23	13	3
18	12	3	24	9	3

Remarks on the Bed of the River, &c.

Although we only pierced the Bed of the River in 24 Places, yet that was fully ſufficient for our Purpoſe, and indeed, I think, they are alſo pretty ſufficient for my preſent Conſideration, upon which I can ſafely conclude, that the Ground oppoſite *Charles-ſtreet*, (where the Bridge muſt be built) is not able to ſupport the Weight of a Bridge; and if you turn back and re-examine the Borings of N°. 5, 6, 7, 8, 9, 10 and 11, you will coincide in Opinion with me; but I do not by any Means adviſe you to depend entirely on theſe Borings, but take a Carpenter with you at low Water, and let him bring a Hand-ſpike pointed at one End with him, and a nine Foot Pantile-lath or a Quarter-four, and let him break through the Cruſt of the Ground, by firſt driving or working down the Hand-ſpike 2 or 3 Feet, and I will venture to engage, that he can thruſt down the Pantile-lath to the Rock, in any Place you pleaſe to fix on thereabouts, eſpecially at 9, 10 and 11; nor need you have any other Implements to prove the moſt Part of our Borings; and theſe Experiments will be of Uſe, and give you a true Idea of the Nature of the Ground you are going to build upon; and that will alſo partly diſcover the Reaſon that the Wooden-bridge before-mentioned, laſted but two Years, and excite your Admiration, that the preſent Bridge has ſtood ſo long, without ſuffering the ſame Fate. I ſhall now lay before you the principal Lines of my Deſign of a Bridge ſuitable to that Place, and effectual Methods for the Accompliſhment of it.

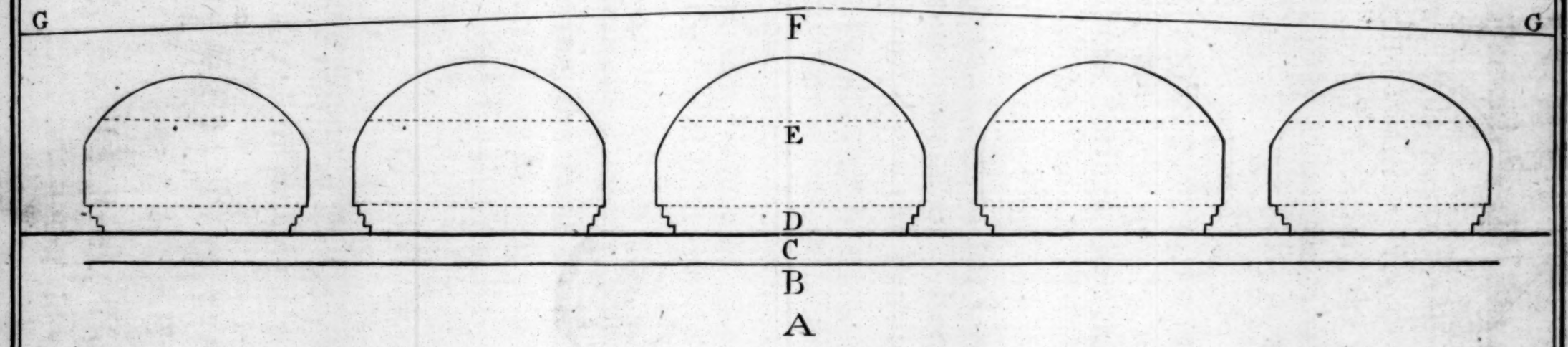
CHAP. XII.

The principal Lines of a Deſign for ORMOND-BRIDGE, *with proper Inſtructions for the Execution thereof.*

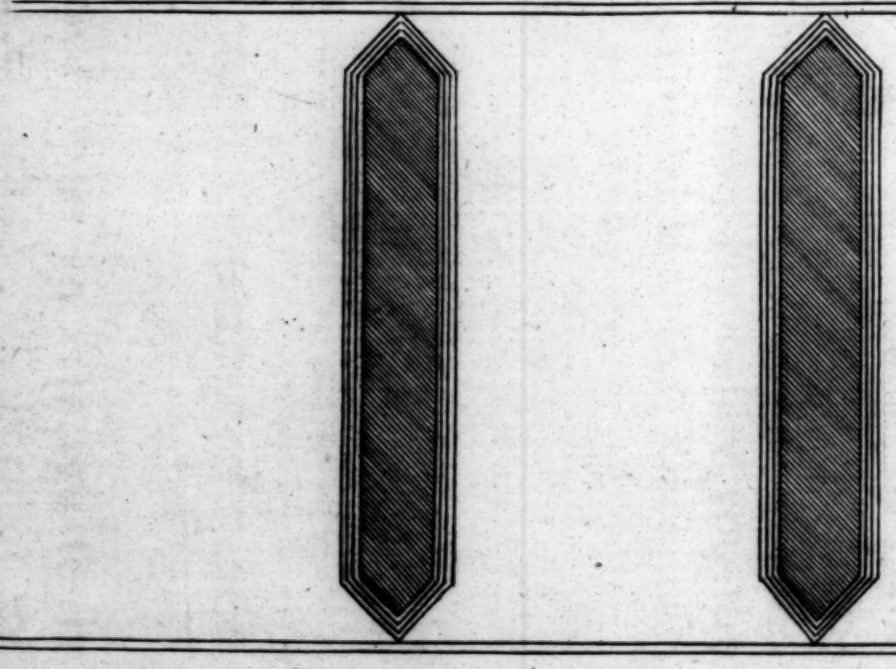
EXPLANATION *of* PLATE XXI. *Scale* 20 *Feet* 1 *Inch.* *Fig.* 1.

NOTE, A. The Rock, (ſuppoſed upon an Average to be about 12 Feet under low Water mark). B. Part of the natural

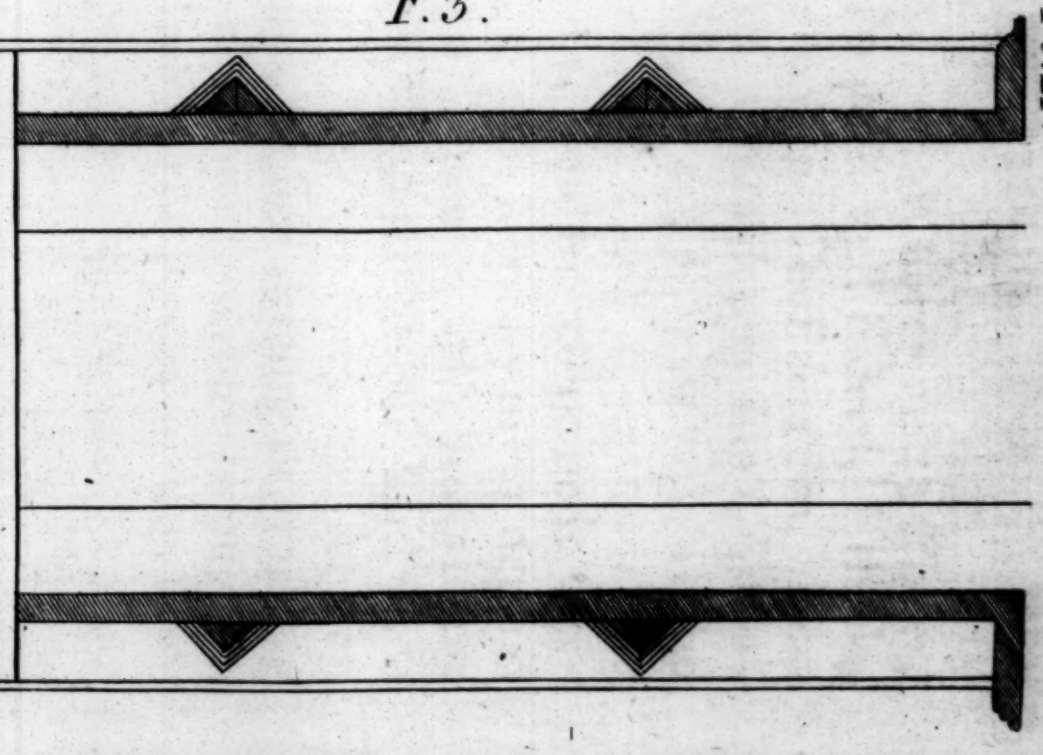
F.1.



F.2.



F.3.



Pl.21.

natural Bed of the River. C. Thorough Foundation of Maſonry, (three Feet high). D. Low-water mark (three Feet above ditto. Foundation). E. High-water mark, (taken at 10 Feet on an Average). F. Pavement, (five Feet from the Soffeto of the Center Arch). From low Water mark to the ſpring of the Arch is 6 Feet. Thence to the Soffeto of the Arch 10 Feet 4 Inches, and F. 5 Feet: In all 21 Feet 4 Inches. G. G. Pavement 19 Feet. Declivity 2 Feet 4 Inches in the Pavement from F to G.

It may not be amiſs here to obſerve, that a great deal depends on a judicious erecting of the Sounding-boards. Try the Depth at ſeveral Ebbs, obſerving that it is much more adviſable to calculate from the loweſt Ebb, for fear of raiſing the Summit of the Pavement too high, and be ſure that all theſe Dimenſions agree together from your low Water mark. The next material Thing is to conſider the Water-ways.

The Voids and Solids, or the Piers and Arches of the preſent Bridge, and of this Deſign compared.

	Preſent Bridge.				This Deſign.			
Plate XX.	Ft.	Inch.	Ft.	Inch.	Plate XXI.	Ft	Inch.	Ft.	Inch.
South Arch - -	20	0	0	0	South Arch - -	25	6	0	0
South Pier - -	0	0	11	3	South Pier - - -	0	0	5	6
2d Southerly Arch -	24	3	0	0	2d Southerly Arch -	28	6	0	0
Ditto. Pier - -	0	0	11	10	Ditto. Pier - - -	0	0	6	0
Center Arch - -	27	8	0	0	Center Arch - -	31	0	0	0
3d Pier - - -	0	0	11	0	3d Pier - - -	0	0	6	0
4th Arch - - -	25	2	0	0	4th Arch - - -	28	6	0	0
4th Pier - - -	0	0	10	11	4th Pier - - -	0	0	5	6
5th or North Arch	20	0	0	0	5th or North Arch	25	6	0	0
Total	117	1	45	0	Total	139	0	23	0

N. B. Abutments 10 Feet each.

In fixing upon the Scite of this Deſign, obſerve that the middle of the Bridge muſt be oppoſite to the middle of *Charles-ſtreet*, but not in direct Line with it, becauſe the River and the Street form an acute Angle, and the Bridge muſt be on right Angles with the Current, otherwiſe the Piers will incline athwart the Stream, which

always ought to be avoided, as far as other Circumſtances may reaſonably admit of it.

Fig. 2. Shews the Plans of the two ſoutherly Piers, and the Incloſure of the thorough Foundation, which muſt at the leaſt be 50 Feet broad in the clear of the Piles that incloſe it. Fig. 3. Shews what the Superſtructure will be when finiſhed.

EXPLANATION *of* PLATE XXII. *Scale* 30 *Feet* 1 *Inch.*

This Plate repreſents the firſt general Plan of Operation in laying the ſoutherly Foundations; wherein note. A. Pool for Pump Engine. B. B. Water Trunks. C. The Pit for building the South Abutment and Pier. D. Pit for building the 2d South Pier, *&c.*

EXPLANATION *of* PLATE XXIII. *Scale* 5 *Feet* 1 *Inch.*

Fig. 1. Plan of the middle Dike of the Coffer-dam, through the Center Arch.

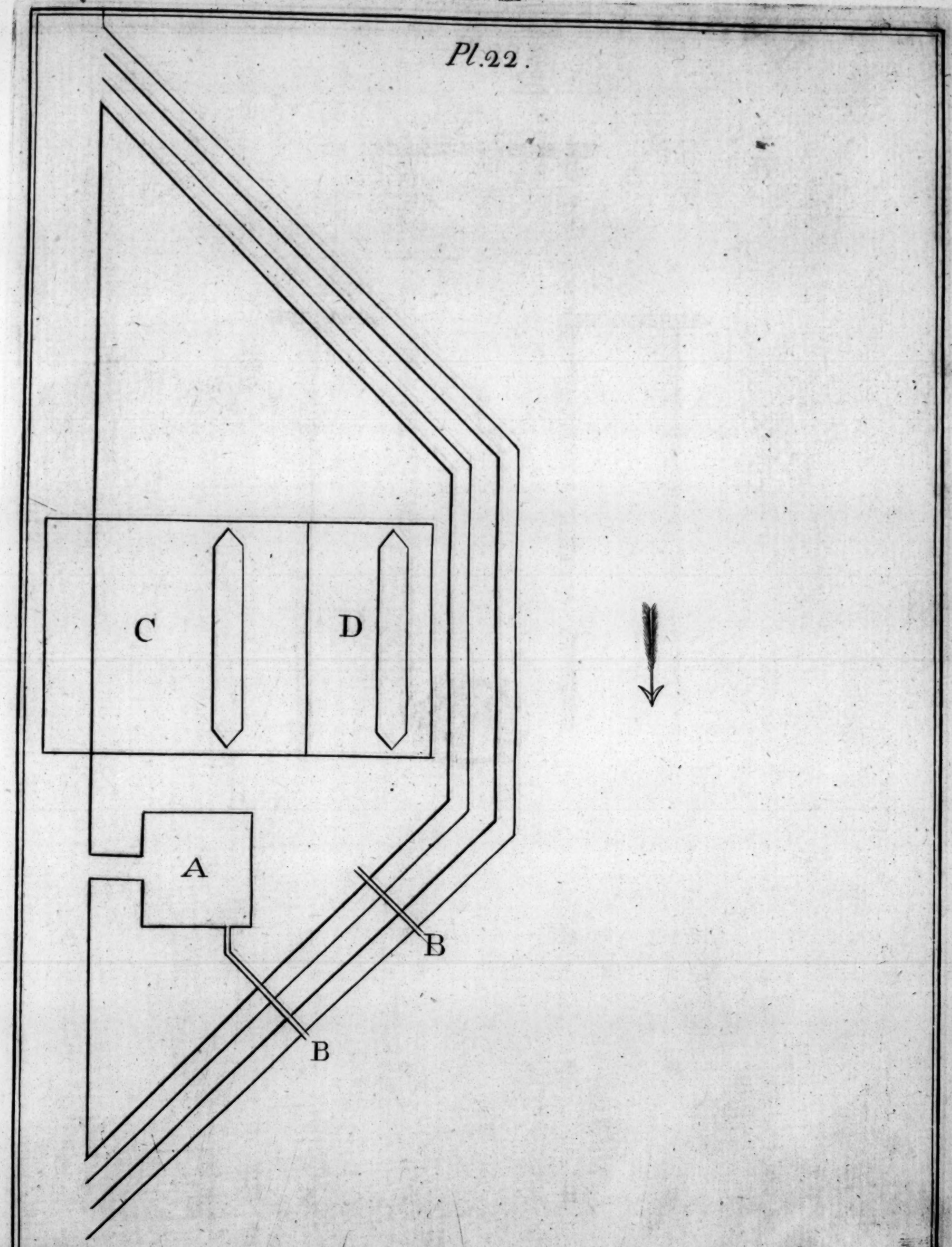
Fig. 2. Conſtruction of the Coffer-dam, wherein note. A. Low-water. B. High-water. *N. B.* After the Frames are drove down as deep as you can drive them, they are to be ſtrained together, ſo as to give them a ſix Inch batter in the middle row, and the outward Rows in the ſame proportion as formerly directed.

Conſidering the exceeding ſoft Ground on which this Dam is to be erected, it is very probable, that after the Clay is put in them, they will be liable to incline either to one Side or the other, and whenever you can perceive that, or you obſerve that the Clay ſpreads out the middle Frame, in either of theſe Caſes, and either within or without the Dam, you are to proceed after the ſame Method already fully laid down in Plate VIII. C. e, f, g and h, explained in Page 32.

EXPLANATION *of* PLATE XXIV. *Scale* 5 *Feet to* 1 *Inch.*

Fig. 1. I apprehend, that I have been ſo explicit on Plate XIII. Fig. 1. that I need not repeat here, as this Draught and Scale may fully

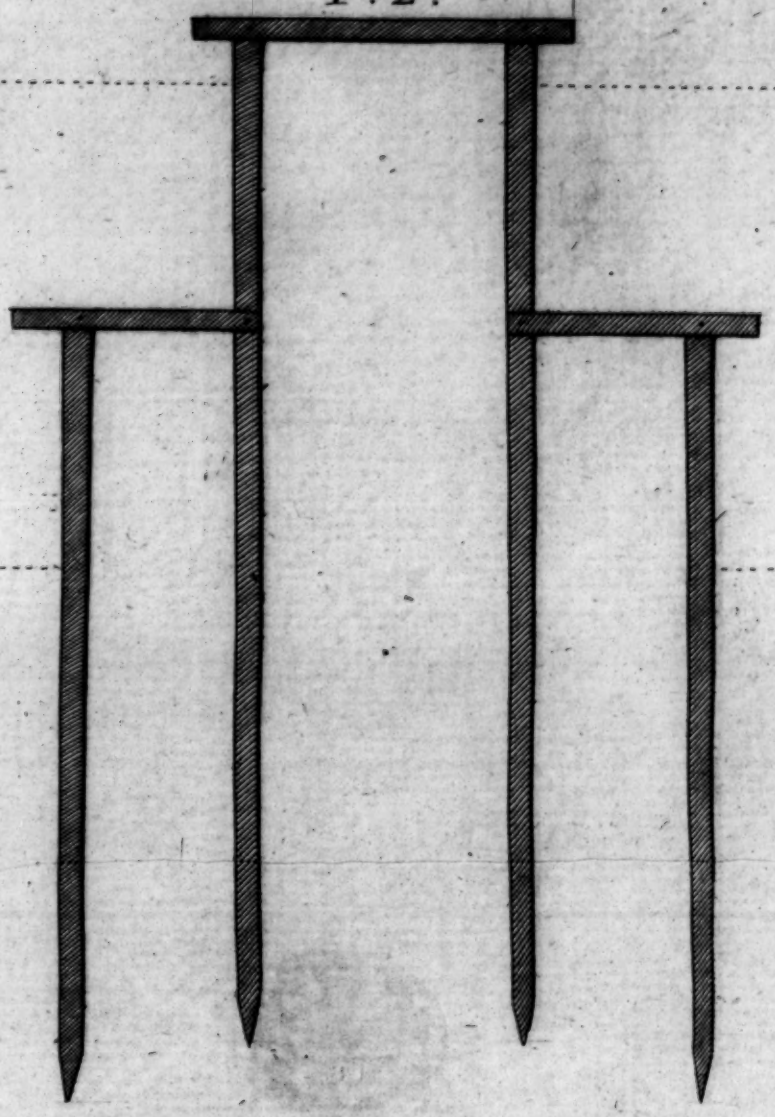
Pl.22.



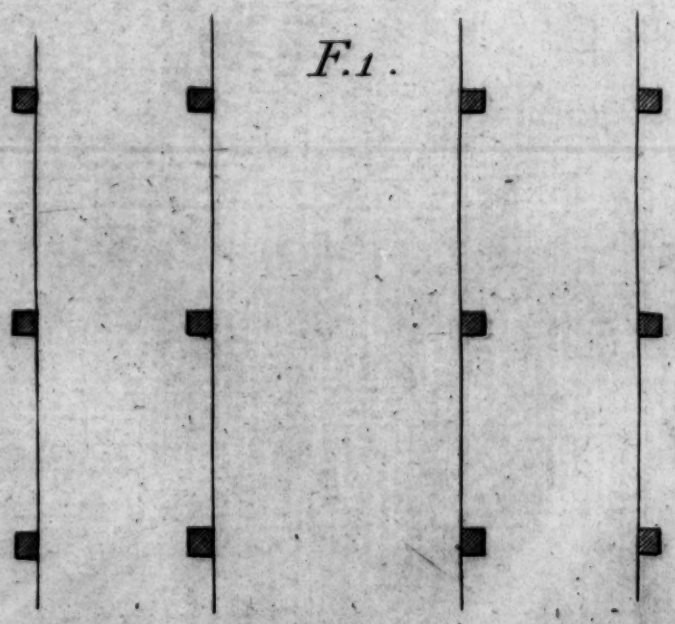


Pl. 23.

F. 2.

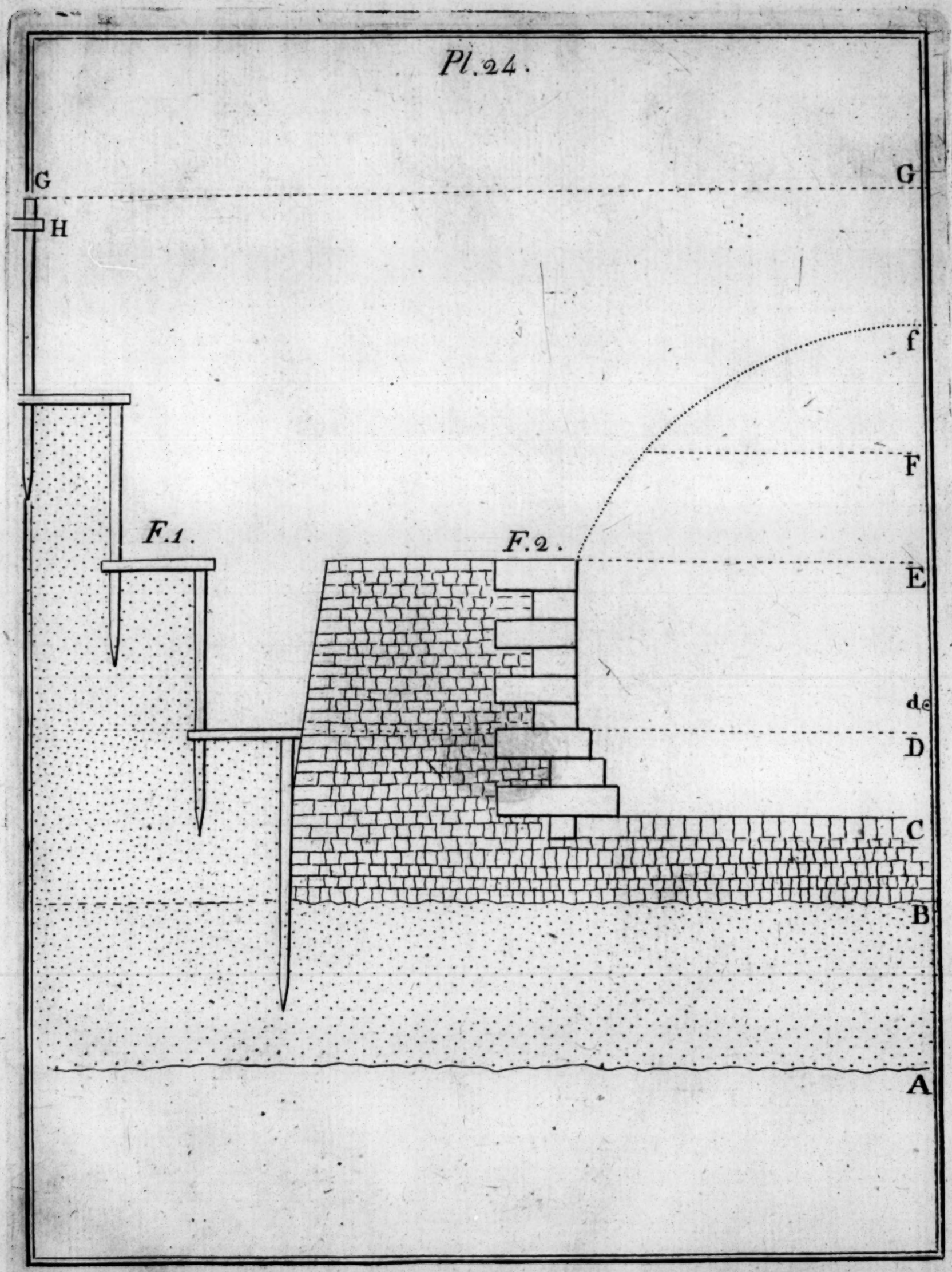


F. 1.





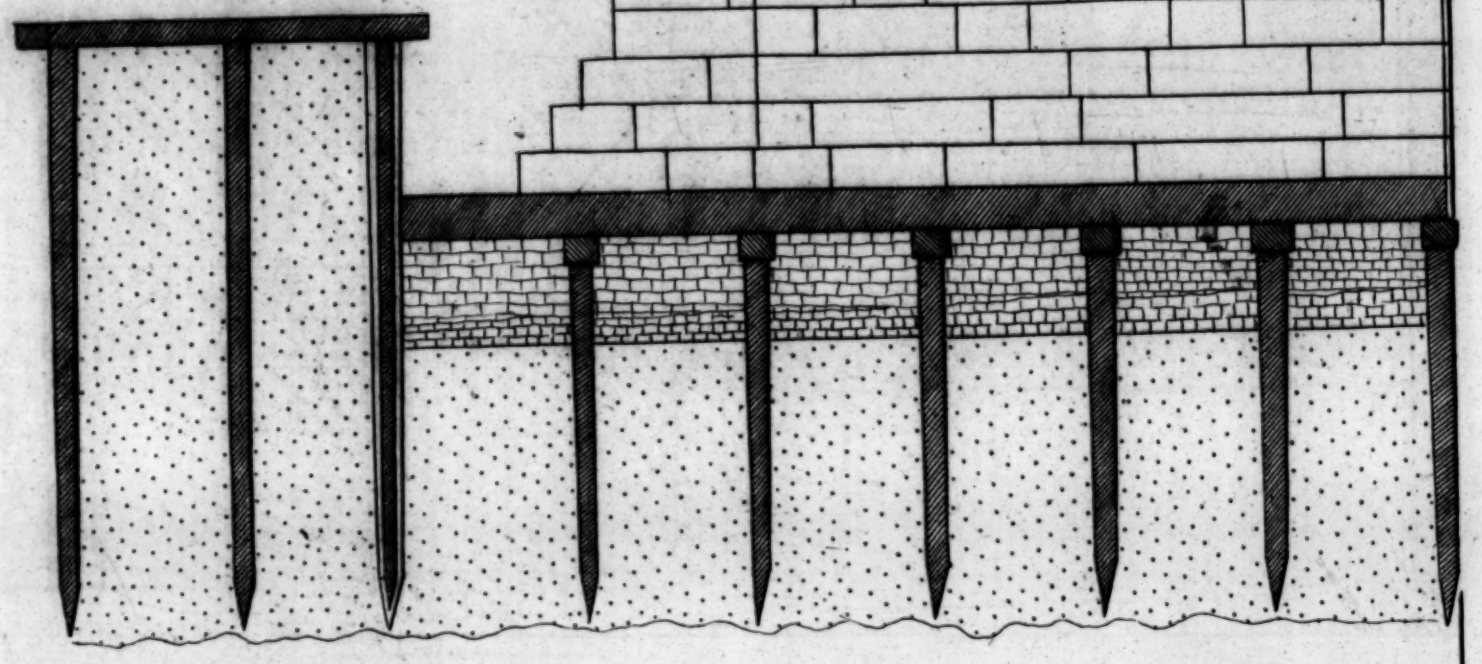
Pl. 24.



P. 25.

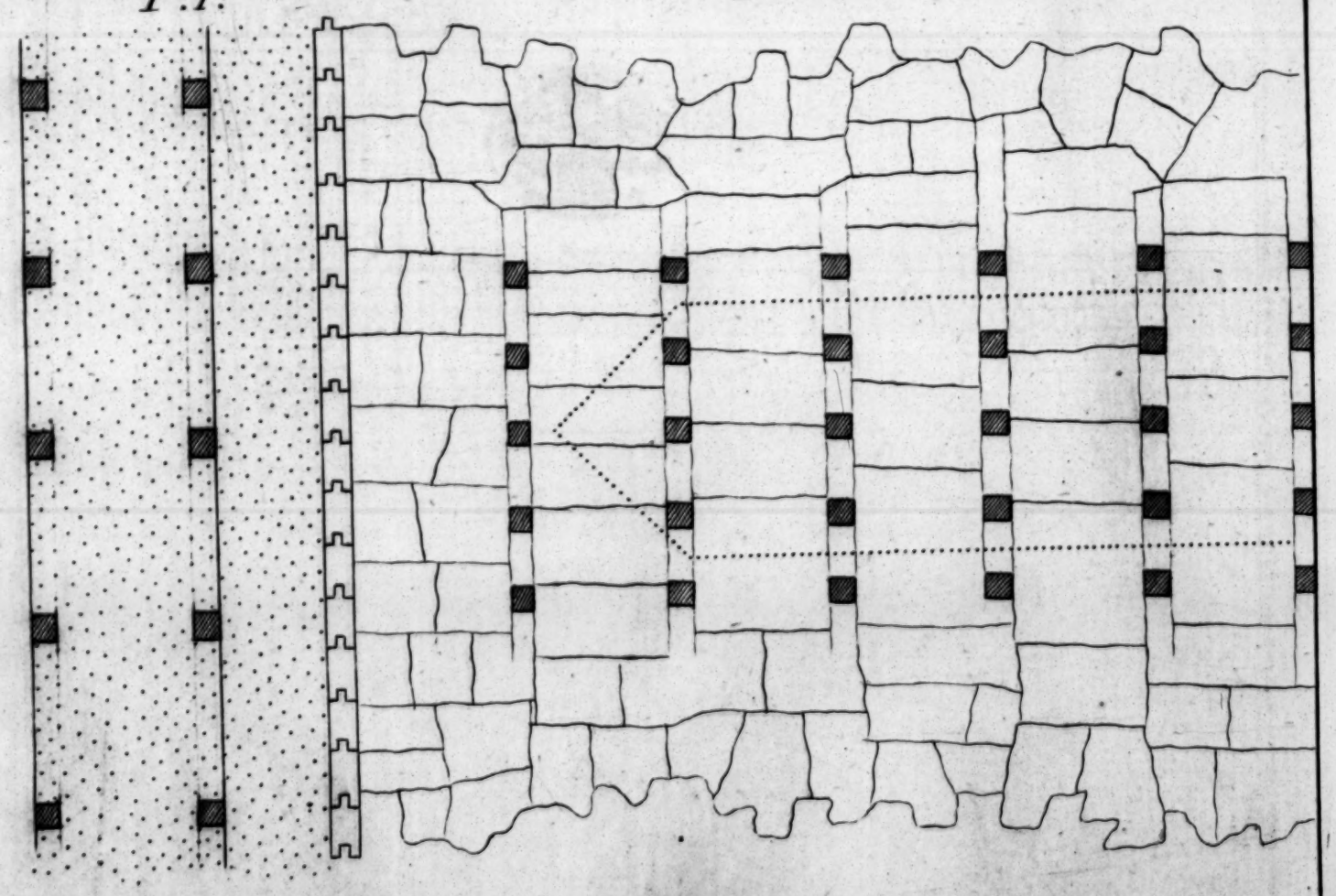
F. 4.

F. 2.



F. 1.

F. 3.



fully anſwer your Purpoſes; only obſerve, that G. is the Superficies of the preſent Pavement, which is 25 Feet from the level of the bottom of the Pit; and if you find it neceſſary, you may go another Foot deeper. H. Is the End of the Land-tye.

Fig. 2. Section of the Land Abutment and half of the South Arch, wherein note. A. The Rock. B. The bottom of the Pit, (unleſs you go another Foot deeper, as above-mentioned). C. The Surface of the thorough Foundation, which is here ſuppoſed to be three Feet high; but if you add the other Foot in Depth to it, do not forget that Foot afterwards in all your other Dimenſions. D. Low-water mark 3 Feet. d. Center from which the Arch was deſcribed. E. Springing of the Arch. F. High-water mark. f. Soffet of the Arch which is 8 Feet 6 Inches, that is $\frac{1}{3}$ of the ſpan from E. to f. G. Surface of the Pavement.

EXPLANATION *of* PLATE XXV. *Scale* 5 *Feet to* 1 *Inch.*

Weſt End of South Pier.

Fig. 1. Is the Plan of the Coffer (or Incloſure of the inner Pit) for laying the Foundations. Fig. 2. Is the Section of the ſame. Fig. 3. Is the Foundation of the Weſt End of the South Pier; wherein obſerve, that there are five Piles in each row, at about 14 Inches aſunder, and about three Feet diſtance in the rows. In the North Piers of *Eſſex-bridge* you may obſerve they were four Feet aſunder each Way, becauſe the Ground was there tolerably ſtrong, but here it is intolerably ſoft, and therefore, it is requiſite they ſhould be drove cloſer; yet we muſt not depend too much upon the Piles, but endeavour to make the Maſon-work as ſubſtantial as poſſible, in order to which, let me recommend the procuring good ſtout rough Flags ſcabbeled to three Feet long (the Diſtance of the rows the long Way) and after laying at the leaſt, half a Foot thick of ſharp Gravel, covered with two or three Inches thick of Roach-lime over your Ground, bed thoſe coarſe ſtrong Flags upon it, which will fill the three Feet rows from Pile to Pile; then throw in Pieces of Flags, that will fill between the Piles the other Way, and

from

from thenceforward, let each Stone ſwim in good ſtrong Mortar, cloſely and carefully wrought. Another Method may be this: Sink the bottom of your Pit ſeven Feet under low Water mark, and allow the Foot before-mentioned to be filled with that Bed of ſharp Gravel covered with Roach-lime, and then your Maſonry will be three Feet as above. The Reaſons for this will be hereafter mentioned.

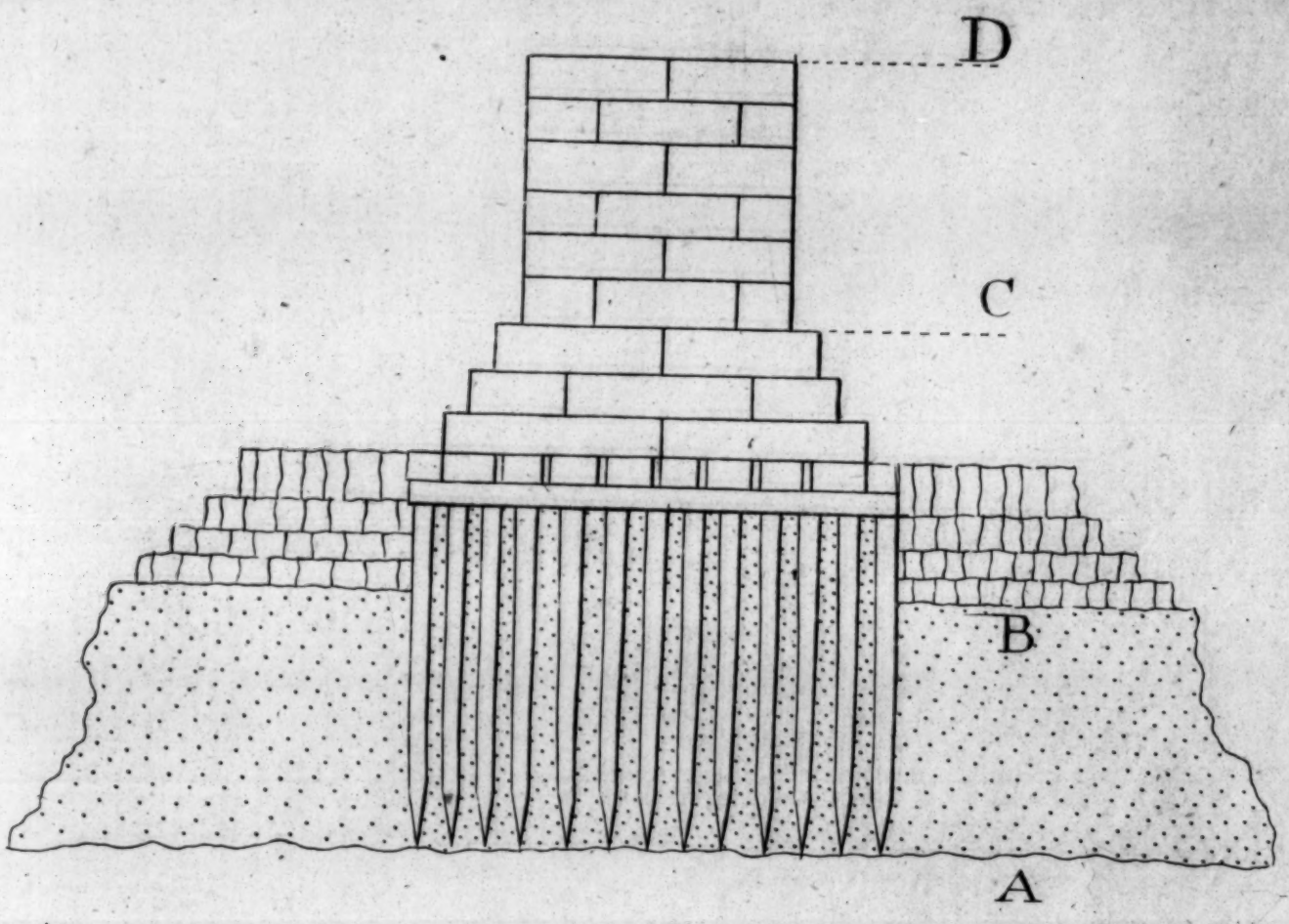
Fig. 4. Is the Section of the Weſt End of the South Pier, and the Foundation on which it is to ſtand: Obſerve, to be ſure of your Diſtance from the Rock, before you cut your Piles to their Length, and let them be rather too long than too ſhort, and in driving them (which will be eaſily done) that every one of them goes down to the Rock: Cut them exactly ſquare and level, ſo that your Caps may lie firm upon them, and be careful, that your ſtretching Beams lie firm and ſolid upon all your Caps. Theſe ſtretching Beams ought to be 50 Feet long at the leaſt (as before-mentioned) if you can conveniently get ſuch, that they may reach quite acroſs the Foundation: That is, the clear of the dovetail Piles that caſe and ſecure it, eſpecially the middle Beam, but the reſt may be proportionably ſhorter; and that the Maſonry be made level to the Heads of the Piles, take Care that the Caps may lie ſolid on them alſo: And the ſame Care is to be taken when you are levelling to bed your ſtretching Beams, and that the Maſons do moſt punctually obſerve the Directions before given for them. The next Pier is to be done after the ſame Manner.

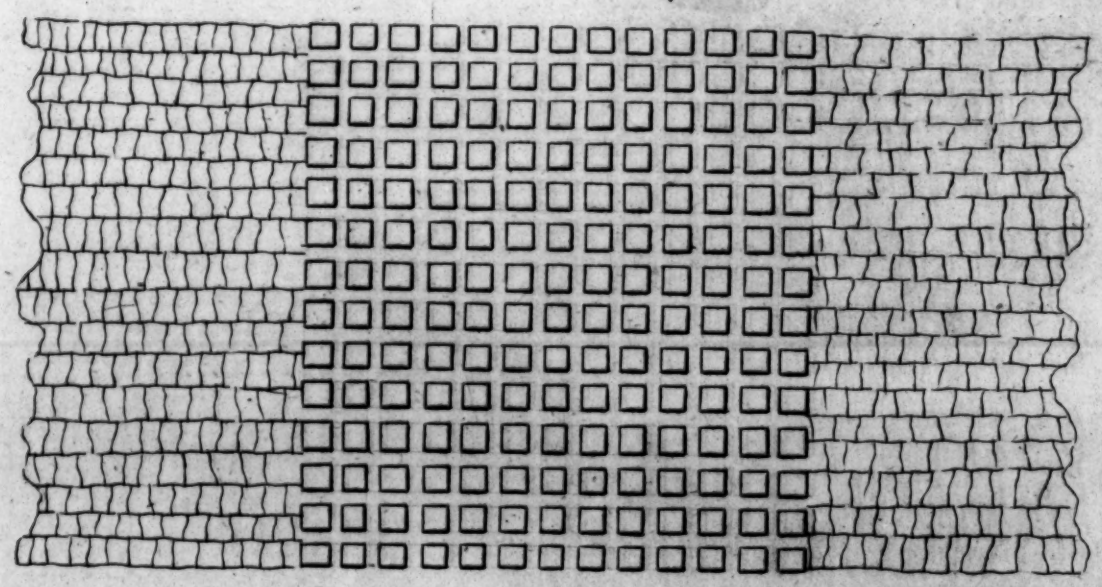
EXPLANATION *of* PLATE XXVI. *Scale* 5 *Feet* 1 *Inch.*

The Plan and Section of the North Pier ſpringing high.

The Bed of the River at this End of the Bridge, being much ſofter than at the other End, you ought to endeavour to make them both alike ſtrong: In order to which, I propoſe that this Pier ſhould ſtand upon Piles. For if you recollect the eleventh boring, I believe you will conclude with me, that notwithſtanding all the Care and Cautions given to the rough Maſons, their Work between the

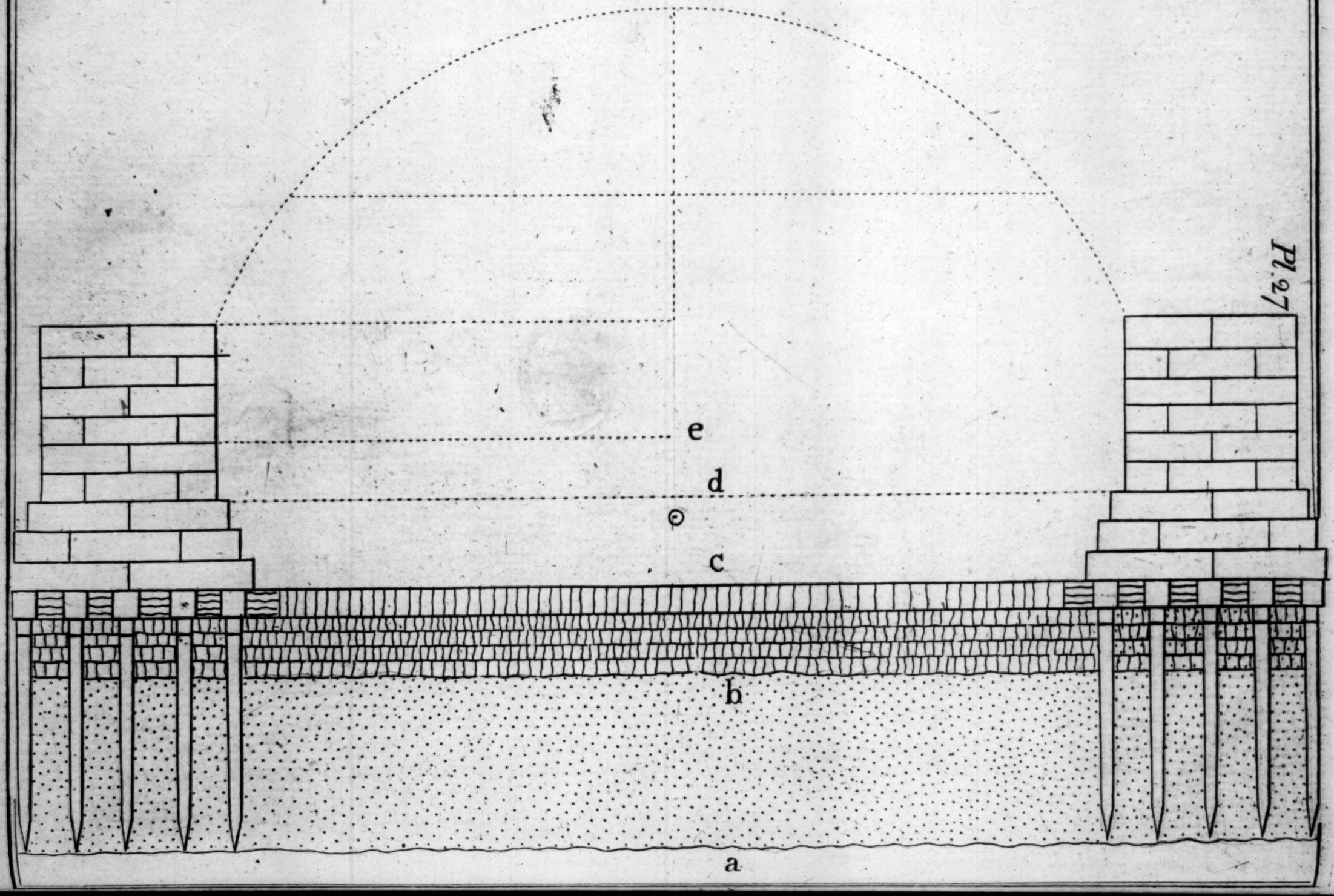
Pl. 26.







Pl. 27



rows of Piles will be in danger of ſubſiding, and ſo that Pier would conſequently and principally ſtand on thoſe ſingle rows of Piles. It muſt, therefore, certainly be the ſafeſt Way to Pile the whole as you ſee it herein drawn, with the grateing of Timber on them. You may obſerve there is a Supernumerary row of Piles at each Side, leſt they ſhould not exactly ſquare with the ſcite of the Pier, and to leave a little ſet-off for your firſt projecting Courſe; the thorough Foundation is to be laid with large well-headed Stones againſt the Piles, and the Spaces between them to be ſtuffed full of ſmall Stones, Roach-lime and Gravel, to keep all firm and ſteady, that they may not lean either to the one Side or the other in that ſloughy Ground. Note, A. the Rock. B. Bottom of the Foundation. C. Low-water, and D. ſpringing of the Arch as before.

EXPLANATION *of* PLATE XXVII. *Scale* 5 *Feet* 1 *Inch.*

Section of the thorough Foundation, and the two middle Piers ſpringing high.

I hope what I have already ſaid has been ſo explicit, that I need not repeat it. If I was to make any Amendments on this, it would be to make the rows of Piles only two Feet aſunder inſtead of three, but that only in this North Pier, as even here, that Pier ſtands on the ſofter Ground of theſe two Piers of this Arch.

I ſhall now again give ſome friendly Cautions, that I could wiſh were deeply imprinted in your Mind as general Rules; that is, never pretend to draw a Deſign, or engage in any Work of this Nature, without moſt ſtrictly examining the Strength of the whole Ground that is to ſupport it; and if you find the Ground under any of the Piers, or any Part of them, is not equally ſtrong, that either by piling, or ſome other effectual Method, you bring the whole upon an Equality, ſo that your Work may ſtand firm and ſecure for Ages to come. If you are to build a Bridge over a navigable River, it might be, that in ſome former Time Ballaſt-men might have drudged a Hole, which was immediately filled up with Slough (which I take to be the Cauſe of the Pier ſinking of *Weſtminſter*

minſter Bridge) upon which, perhaps, one End of a Pier might ſtand, or under one End of a Pier there may be a Rock, and under the other ſoft ſpringy quick Sands or the like; or further, perhaps, you may have a ſolid Rock on one Side of a River, and very ſoft Ground on the other, from all which, and many other ſuch Caſes, it is indiſpenſably neceſſary to ſearch diligently into the Bed of the River, at the leaſt, within the full extent of the Ground you intend to occupy: And conſider alſo, how will you be able to anſwer for your Conduct, in pretending to build a Bridge that for aught you know, may tumble down before it is even finiſhed, or at beſt may not ſtand many Years till it begins to totter or lean to one Side or other; and if it is over a navigable River, recollect what I told you before of the Bridge built by *Trajan*, that ſo totally deſtroyed the Navigation of that Part of the *Danube*, that they were forced to cut a new Channel for the trading Veſſels, to avoid the Ruins of it, which you know cannot be done in any trading Town or City.

We have heard that the finding out the Diſeaſe, is one half of the Cure, and there are Remedies for all ſorts of Diſeaſes, but the great Art is to diſcover them; and in the preſent Caſe, when you know the Evils you are to guard againſt, you conſequently ought to find out Ways and Means to prevent them. Your Bed of the River we will ſuppoſe, in the Condition we have been conſidering; ſurely then, there cannot be a more effectual Method to ſtrengthen and bring the Bed to a ſufficient Equality, than that which the three eminent Architects have mentioned of turning off the Water, by making an Encloſure or Coffer-dam: In the Execution of which, you will find much Pleaſure and Satisfaction, provided you obſerve this repeated Advice, that is, to ſpare neither Time nor Trouble to drudge out and remove all the Stones and Rubbiſh from under the Dikes of your Dams, and if you do ſo, I can anſwer for it, that every Thing elſe may be moſt effectually executed.

But it is alſo proper to apprize you, that among the ſeveral other Methods that have hitherto been made uſe of, there is one not yet mentioned, which ſoft ſlutchey Ground, perhaps, will move ſome Perſons to recommend, and that is, piling for the Piers, or as Mr. *Labely* deridingly calls it, building upon Stilts; and you ſhall now under-

underſtand the Difference between that Method, and this which I recommend.

The general Method of building Piers of Bridges upon Piles is this: They drive down Piles cloſe together to near low Water, cut them level and ſquare at the Heads, and lay thereon a Grating of Timber, whereon they begin to lay the Cut-ſtone Work of their Piers, the bottom of which may probably be about two or three Feet above low Water: This is a very tedious Way, becauſe the Tide always interrupts their Proceedings, but in Caſe that ſhould be diſpenſed with, yet conſider how feeble ſuch Piles would ſtand in ſoft ſlutchey Ground, that the leaſt Preſſure from either Side, would give them all a lean to the oppoſite Side: Beſides, theſe Piles muſt have ſeveral rows of Piles drove round them, which will leave very little Room for the Water, and that will increaſe its Strength, by which it will tear up the Bed of the River between the Piers, and require continual repair from the Day they conclude the Work finiſhed, and ſo the Bridge would continue in a tottering Condition, and bring a conſtant Charge either on the Corporation of the City, or the Public, and probably would ſoon ſhare the Fate of Sir *Humphrey Jervis*'s Wooden-bridge before mentioned, and many others.

Now obſerve in ſaid Plate XXVII, that a. is the Rock; b. Bottom of the thorough Foundation; c. Surface of the ſame; d. low Water mark; e. would probably be about the Surface of the Grating, whereon the Stone-work would begin, and ſo the Stone-work of this our thorough Foundation beginning at b. would be about 8 Feet below that of theirs, and all that ſoft Slutch would be thrown out, and a firm Stone-work put in the Place of it, which as I obſerved before, would wedge in and keep thoſe Piles tight and firm together, and whence, your Overſeers may be able to determine which of theſe Methods are moſt eligible.

It is not improbable, that the Perſons who recommend this Method of building the Piers upon Piles, will offer this Argument to enforce it: That it will be a vaſt deal cheaper than the Method which I propoſe, and I admit, that for the preſent it may be ſo; but ſuppoſing it were poſſible to make it to ſtand any Time, it

would be infinitely more expenſive toward the Concluſion, beſide the danger of its falling immediately after the Centers are ſtruck.

Mr. *Labely* has informed us Page 40, " that at *Moulins*, in *France*, they attempted to build a Stone-bridge upon Piles, driven about 15 Feet into the Bed of the River, the tops of which were ſtrongly faſtened together, and reached about five or ſix Feet above the Surface of the Bed of the River, but the Moment they attempted to caſe the Centers on which they had turned the Arches, the whole fell into Ruin." Therefore, be adviſed and conſider, that you have now before you effectual and proper Methods, by which you may eaſily accompliſh this Work, all fully proved and ready to be put into Execution, with numerous Cautions diſperſed throughout the whole, which you know was not the Caſe with me, who had every individual Thing to invent and to contrive, ſo as to anſwer theſe Purpoſes; never having either ſeen, heard, nor even read of any of them, ſaving only what I have already mentioned: And therefore, you will find, that you will have nothing to do but to follow theſe plain and eaſy Methods, all of which you are now made fully acquainted with.

END *of* PART *the* FIRST.

BUILDING in WATER.

PART II.

Concerning an Attempt to contrive and introduce quick and cheap Methods, for erecting ſubſtantial Stone-buildings and other Works, in freſh and ſalt Water, quaking Bogs or Moraſſes, for various Purpoſes; fully laid down and clearly demonſtrated, by TWELVE PRACTICAL PROPOSITIONS, but not in any Caſe exceeding ten Fathom deep: Together, with a Plan for a ſpacious and a commodious Harbour for the *Downs* in *England*, projecting to 20 Feet deep at low Water.

CHAP. XIII.

Concerning ſome Methods made uſe of by the Antients, and on particular Qualities of Lime, Mortar and Grout.

MY Thoughts on this Subject, took their riſe from an Obſervation I made on our taking up the Foundations of *Eſſex-bridge*, where we found that the Bed of ſharp Gravel, on which the Piers had been built, was actually petrified ſeemingly into a cloſe ſolid Stone, by the ſmall Quantities of the petrifying Qualities of the Lime, that had ſunk down into it, in about 70 Years, but principally ſince erecting the Effigy in 1722, which you have ſeen particularly noted in Chap. VI. Sect. 2. Together, with what I obſerved concerning the exceeding great Strength of the Mortar in the Foundation of the Pier, which I repaired in *Ormond-bridge*, and which is mentioned in my explanatory Notes on Plate XX. Letter A.

Having taken proper Notes and Obſervations thereon, and compared them with what *Palladio* has mentioned in his 1ſt Book, Ch. 9. Sect. 6. concerning ſome " Walls called *Reimpiuta*, or *Coffer-work*, " which were made by the Antients, by taking Planks laid Edge-" ways, according to the Thickneſs of the Walls, filling the Void " or Space between them, with Cement and all ſorts of ſmall Stones " mingled together, and continued after this Manner from Courſe " to Courſe: There are Walls now at *Sirmion*, upon the Lake *di* " *Garda*, built after this Manner." I ſay theſe principal Matters, and what I have learned from ſeveral other *Roman* Au hors and antient Hiſtorians, have at length, produced what I am now about to lay before you, not in the leaſt doubting, but you will take them into Contemplation, and improve the hints I ſhall give you, ſo far as you ſhall find them worthy your Notice; and likewiſe, to be productive of public or private Utility, thoſe being my Motives for writing and publiſhing theſe Sheets, which I confeſs, has brought on me a very arduous Taſk, becauſe I am conſcious of my great Incapacity to perform ſuch an undertaking; but yet, I preſume, that if through the Courſe of my little Practice, any uſeful Occurrences have happened in my Way, it is better to leave them in the Poſſeſſion of the Public, even irregularly cloathed in their poor homely ſpun Apparel, than to carry them with me to my Grave. And now as you know the Motives that have actuated my Endeavours, and the End I propoſe in this Part of my Work, and as I have ſuch great Objects in View, I hope I ſhall be honoured with a ſerious and candid Peruſal: That the Scope and Deſigns of this Work may be regarded, the real Importance of my Remarks and Contrivance conſidered, and not my Language or Expreſſions to be anatomiſed, as if thoſe only were to employ the Attention of my Readers; for I ſtudy neither Stile nor Diction, any further than what I think neceſſary to communicate and render my Sentiments intelligible to my Readers, moſt zealouſly endeavouring to reduce all my adequate Ideas into the Forms and Figures exhibited on the enſuing Plates, which henceforward muſt principally govern and direct the Thread of my Subject.

SECT.

SECT. I.

Concerning Coffer or caſed Walls or Foundations, abridged from L. B. ALBERTI.

WHAT *Palladio* calls Coffers, the Tranſlators of *Alberti* call Caſes, which in Fact are the ſame Things. In *Alberti*'s 3d Book, Ch. 5. he recites various Methods made uſe of by the Antients, both in laying Foundations and in building Walls in Caſes, and among the reſt, he expreſſes himſelf in theſe Words: " I have obſerved, that in other Places the Antients, who were won- " derfully expert in making of great Works, followed different " Methods in filling up the Foundations. In the Sepulchre of the " *Antonini*, they filled them up with little Pieces of very hard " Stones, each not bigger than an Handful, and which they per- " fectly drowned in Mortar. In the *Forum Argentarium*, with " Fragments of all ſorts of broken Stones. In the *Comitia*, with " Bits of the very worſt ſorts of ſoft Stones.--- I have known other " Inſtances, where the Antients have much the ſame ſorts of Foun- " dations, and Structures too of coarſe Gravel and common Stones, " that they have picked by chance, and which have laſted many " Ages.

" Upon pulling down a very high and ſtrong Tower at *Bologna*, " they diſcovered that the Foundations were filled with nothing but " round Stones and Chalk, to the Height of nine Feet, the other " Parts were built with Mortar; we find, therefore, that very diffe- " rent Methods have been uſed, and which to approve moſt, I con- " feſs myſelf at a loſs, all of them having endured ſo long firm and " ſound; ſo that I think, we ought to chooſe that which is the leaſt " expenſive, provided we do not throw in all Manner of old " Rubbiſh, or any Thing apt to moulder." After his mention- ing many other Things concerning Walls, he concludes this Chap- ter with theſe Words, " I therefore lay it down as an indiſpenſable " Rule, that all the firſt Courſe of Work from the level of the " Foundation, ſhould be compoſed of the hardeſt, ſoundeſt and

" largeſt

" largeſt Stones;" but after that Courſe he treats largely of carry-
" ing up the out Sides, with cut Stones and filling (or ſtuffing as he calls it) the inſide with ſmall Stones, and Lime-liquid: And he concludes his 8th Chapter with this Obſervation, " Laſtly, we are " taught, what I find conſtantly obſerved among the Antients, " *never to admit any Stone among the ſtuffing that weighs above one* " *Pound*; becauſe, they ſuppoſed that ſmall Stones united more " eaſily, and knit better with the Cement than large ones."

In his 10th Chap. are theſe Words, " There are ſome, who ob-
" ſerving here and there in the Works of the Antients, large Stones " which where they join ſeem daubed over with red Earth, I ima-
" gine that the Antients uſed this inſtead of Mortar." Chap. 11th, he ſays, " but as we ſhall ſometimes be obliged to make uſe of " other ſorts of Stones, whereof ſome are not cemented with " Mortar," or Grout I ſuppoſe, " but only with Slime," ſome tell us, " that the Slime which is uſed for Cement, ought to be like " Pitch, and that the beſt is that which being ſteeped in Water, " is ſloweſt in diſſolving, and will not eaſily rub off. Others com-
" mend the ſandy as beſt, becauſe it is moſt tractable.---In antient " Structures, we often meet with very ſtrong Walls, made of no-
" thing but Rubbiſh and broken Stuff, theſe are built like the Mud " Walls in *Spain* and *Africa*, by faſtening on each Sides Planks or " Hurdles, to keep them together till they are dry and ſettled, but " herein they differ, for ſome ſay, that the Antients filled up " their Work with Mortar-liquid, and in a Manner floating." Numerous other Authors have tranſmitted theſe or the like Methods; but theſe are ſufficient for our preſent Purpoſe, let us, therefore, in the next Place conſider the Natures and peculiar Qualities of ſome of the Materials, which we are to make uſe of, for there are many Things neceſſary to be conſidered and ſtrictly obſerved, before we enter into a full Diſcuſſion of our Subject.

SECT.

SECT. II.

Concerning Lime, Mortar and Grout.

I HAVE from my Childhood, been well acquainted with the Nature of Lime and Sand made in Mortar, of all ſorts, that have been uſed in Buildings in theſe Countries, and tried numerous Experiments with them; on which, together with what I have obſerved and learned from old experienced Workmen, during the Courſe of upwards of ſixty Years, I think, I can ſafely affirm, that good Mortar, that is, Mortar made of pure and well-burnt Lime-ſtone, and properly made up with ſharp, clean Sand, free from any ſort of Earth, Loam or Mud, will within ſome conſiderable Time actually petrify, and as it were, turn to the Conſiſtence of a Stone. I remember I had one of my Remarks from an old *Scotch* Maſon, which I ſhall give you in his own identical Words, that is,

When a hundred Years are paſt and gane,
Then gude Mortar is grown to a Stain; (or a Stone.)

My Father (who was a Workman about the Year 1675) often told me, and my own repeated Obſervations convince me, that the Methods Maſons practiſed in former Times, in building Churches, Abbeys, Caſtles or other ſumptuous Edifices in this Country, was to this effect. After they laid the out-ſide Courſes with large Stones, laid on the flat in ſwimming Beds of Mortar, they hearted their Walls with their Spawls and ſmalleſt Stones, and as they laid them in, they poured in plenty of boiling Grout, or hot Lime-liquid among them, ſo as to incorporate them together, as if it were with melted Lead, whereby the heat of it exhauſted the Moiſture of the out-ſide Mortar, and united moſt firmly both it and the Stones, and filled every Pore (which as the Maſons term it) ſet, that is, grew hard immediately, and this Method was taught to our antient Maſons, by the *Romiſh Clergy* that came to plant *Chriſtianity* in theſe Countries, and I affirm, that in many of ſuch old Buildings, I have ſeen the Mortar, as it were, run together and harder to break than the Stones were.

But with reſpect to the Matter in hand, I admit that Mortar will not ſet or grow ſo ſoon hard in Water as upon Land; but I am fully convinced, that good Mortar will in reaſonable Time grow as firm and as ſubſtantial in Water as upon dry Land; but not dwelling upon mere Reports, I ſhall come to Facts, and I do alſo affirm, that in pulling down *Eſſex-bridge*, and repairing *Ormond-bridge*, we found the Mortar of the lower Courſes of the Piers better cemented to the Stones, than it was in the upper Works; for a wet Stone or a wet Brick imbibes the Mortar, and holds it faſter than a dry Stone or Brick will do; the Duſt and Dryneſs of either cruſts the Mortar immediately, and the wet Stones or Bricks ſuck and unite with it, as for inſtance, take two Bricks equally well burned, wet one of them and lay it on a Bed of Mortar, and at ſome Diſtance from that lay on the other dry, let them lie ſo as long as you pleaſe, and then take them up, and you will find the wet Brick will bring up its Bed of Mortar with it, but the dry Brick will ſeparate and leave its Bed of Mortar behind it.

There are ſeveral ſorts of Lime-ſtone, ſome indeed, ſet much ſooner and harder under Water than others, but any good Lime properly mixed, and tempered with ſharp clean Sand, will bind and cement as effectually under Water as above it, as I hinted before.

What I mean by good Lime, is that which is made of clean, cloſe-grained Lime-ſtone. All Marble is Lime-ſtone, but all Lime-ſtone is not Marble. All Marble will take a poliſh, but all Stones that will burn to Lime, will not take a poliſh. For inſtance, Chalk will make Lime, but it will neither poliſh nor make good Lime for any Purpoſe; therefore, I adviſe you to chooſe the cloſeſt grained, the hardeſt, and conſequently the heavieſt Lime-ſtone for any Work, but particularly for Water-works.

I need not explain what I mean by ſharp, clean Sand, but I ſhall give this one Caution, that it is better to put too much Sand in your Mortar than too little. I know Workmen chooſe to have their Mortar rich, becauſe it works the pleaſanter, but rich Mortar will not ſtand the Weather ſo well, nor grow ſo hard as poor Mortar will do; if it was all Lime it would have no more Strength in Compariſon, than Clay.

Now

Now let us ſuppoſe, that a Peck of Roach-lime was ſlacked into White-waſh, and then mixed with two or three Barrels of ſharp Sand, ſo that every individual Particle of Sand partook, and as it were, got a white Coat of this Liquid-lime, ſuch Mortar, that would only appear to be mere Sand, ſuppoſing ſuch could be wrought into Mortar, would ſooner harden and petrify, either in or out of Water, than if there had been ten Times that Quantity of Lime made up with it; but nevertheleſs, obſerve, that I do not recommend that Proportion for Mortar, though it might anſwer for our preſent Purpoſes extremely well.

It is not within my Province to account for the petrifying Qualities of Lime-ſtone, Lime or Lime-water, though I have often heard, ſeen and read of ſeveral very remarkable Inſtances of each of them, but it is ſufficient for my preſent Purpoſe, that they have theſe petrifying Qualities to great Degrees; but all ſorts of Lime-ſtone have not this Quality in the ſame Proportion, yet I believe, no Lime-ſtone whatever can have more excellent Qualities than ſuch as we have in, perhaps, every County in the Kingdom: And indeed, it has ſome uſeful Qualities not much known among the Generality of Workmen, as for inſtance, our Lime-ſtone will make exceeding good Tarraſs for Water-works, for which purpoſe you are to prepare it thus: Get your Roach-lime brought to you hot from the Kiln, and immediately pound or rather grind it with a Wooden-maul, on a ſmooth large Stone, on a dry boarded Floor, till you make it as fine as Flour, then without loſs of Time, ſift it through a coarſe hair or wire Sieve, and to the Quantity of a Hod of your ſetting Mortar (which on this Account ought to be poorer than ordinary) put in two or three Shovels-full of this fine Flour of the Roach-lime, and let two Men for Expedition ſake, beat them together with ſuch Beaters as the Plaiſterers make uſe of, and then uſe it immediately. This, I can aſſure you will not only ſtand as well, but is really preferable to any Tarraſs.

I will give you another Inſtance which will be hereafter found to come within our Subject, *i. e.* the making Ciſterns in which Tarraſs is generally uſed in ordinary Work, build all your outſide and inſide Rows or Courſes with wet Bricks, and with Tarraſs-mortar made as above directed; obſerving, that your Mortar is to

be a little too ſoft for Work, and then the heat of the Lime-flour will bring it to a proper Conſiſtence immediately; but never throw Water upon it when you are beating it, for that will chill and ſlack your Lime-flour, which you ought moſt carefully to avoid, but make the Men temper it with the utmoſt Expedition, and what you want in Water to make it fit for your Work, give it in Elbow-greaſe; and this Rule ought to be obſerved in making all ſorts of Mortar.

The Grout which you lay your middle Row with, muſt be thus made (in a Tub or Bucket) pour your Water on the Roach-lime, which muſt be pure and well burned, very leiſurely; and when it is boiling, you may ſtrain it through either a wire or hair Sieve, ſo as it may be tolerably free from Stones, and then let it be uſed directly, and be ſure your Sand is ſharp and clean, and when you are uſing it, do not take the thin that is uppermoſt, but ſtir it up and take plenty of the Sand with it; but in Maſons Work, when the outſide and inſide Courſes of cut Stone are ſet, pour in this boiling hot Grout, and inſtantly lay down your middle Courſe of wet Bricks between them, in double or ſingle Rows of Stretchers, braking Joints as uſual, according as the Largeneſs or Smallneſs of the Work may require, and that will preſs and ſqueeze the Grout into all the inſide Pores that are next to it, and ſo they will all unite, and by the heat of the Grout and Dryneſs of the Bricks, they will all ſet together immediately, and become ſtaunch and ſolid; but if you were making a Ciſtern of rough Stone, mix one fourth of the Powder of Tiles, or well-burned Bricks with your Mortar.

CHAP. XIV.

Coffer-work applicable to various domeſtic Purpoſes, as introductory to building in deep Water.

I HAVE already obſerved, that the Word which the Tranſlators of *L. B. Alberti* have rendered *Caſes*, the Tranſlators of *Palladio* have rendered *Coffers*; and that it is evident, thoſe two Words convey to us the ſame Thing in Fact; but in what I am now

now about to lay before you, I have confined myſelf to the Word tranſlated into *Engliſh* from *Palladio*, that is, *Coffer-work*, as I apprehend for ſeveral Reaſons, it is moſt proper for our Purpoſe; and as we have now fixed on a technical Term for this Method of working, let us in the next Place, endeavour to apply and extend that Method to building in Water, wherein we ſhall have great Occaſion for Timber.

SECT. I.

Concerning Oak and Fir Timber.

WE have very little Timber now of the Produce of this Kingdom of any kind, but large Quantities of both Oak and Fir imported; on which two ſorts, I ſhall make a few Remarks.

Oak, is generally allowed to endure all Seaſons and Weathers, better than any other ſort of Timber, and ſome People are of Opinion, that it is the beſt of all others in Water. I know the Pier or Piles, which we began to run out in this Harbour about the Year 1728, have long ſince ſufficiently proved, that it was not by any Means adequate to that Purpoſe, tho' I do believe, that there is not any Country that produces better Oak Timber than ours, notwithſtanding, thoſe Piles rotted and decayed in a very ſhort Time; but whether that was owing to the Nature of that particular Timber, or to any Thing peculiar to our Harbour, I know not, but it reported there is a ſort of Worms that either breed in or are nouriſhed in thoſe Piles, that totally deſtroy them.

There are, indeed, ſeveral Methods that have been made uſe of to preſerve Timber. Sir *Hugh Platt*, informs us, that the *Venetians* make uſe of one, which ſeems very rational, *viz.* to burn and ſcorch their Timber in a flaming Fire, continually turning it round with an Engine, till it has got a hard black cruſty Coal upon it.--- Others inform us, that the *Dutch* preſerve their Gates, Portcullis's, Draw-bridges, Sluices, *&c.* by coating them over with a Mixture of Pitch and Tar, whereon they ſtrew ſmall Pieces of Cockle and

other Shells, beaten almoſt to Powder and mixed with Sea-ſand, which incruſts and arms it wonderfully againſt all aſſaults of Wind or Weather; but for my own Part, I conclude, that the *Venetian* Method is preferable, becauſe I believe, it is the Sap that is either in Oak or Fir, that is the principal Cauſe of their decaying ſo ſoon. Beſides, that Sap probably breeds and nouriſhes the Worms that are natural to it, but there are not any Worms peculiar to the Water that I have ever heard of.

Worms generally breed in the Sap of all kinds of building Timbers, and have a powerful Effect on them, either without or within Doors; and all old and dry ſoft Woods breed them in great Abundance, juſt as Mites are bred in Cheeſe; and ſome of theſe Worms are a quarter of an Inch in Length, and near a tenth of an Inch in Thickneſs; and in very ſooty old Cabbins where ſoft Woods are generally made uſe of, they are to be found in great Abundance. For theſe Reaſons, you ought to be exceeding careful how you make uſe of any ſort of ſappy Timber, but particularly in all Works that ſtand the Weather, for the Sap is of a corroſive Nature, and for that Reaſon ought not to be made uſe of, eſpecially before it is a little ſeaſoned in any Work that requires to be durable.

I know there are Carpenters who pretend it is neceſſary to paint their Work directly, and I admit that in ſome Caſes it may; but it ought to be done with Judgment, and not merely to varniſh over and hide the Imperfections of their Work. As the Preſervation of Timber is a Subject ſuitable to our preſent Purpoſe, I adviſe you never to paint either green or ſappy Timber of any Kind.

When I was building the Manſion-houſe of *Ramsfort*, one Day after Dinner, Mr. *Ram* obſerved to his Company, that he had ſome Time ago, cut up ſome of his own Fir Timber into Scantling, out of which he had a great Number of Field-gates made, and that ſeveral of them that had been hung up near his Houſe, he had had painted immediately, but thoſe that were at a Diſtance through ſeveral Parts of his extenſive Demeſne, were not painted; that thoſe which were painted were all quite rotten, but thoſe that were not painted continued firm. The Company ſeemed ſurprized at this Information, and Mr. *Ram* enquiring of me the Cauſe of this apparent

rent Phænomenon, I readily anſwered, that the painting of the ſappy Wood, encruſted and confined the Sap, and prevented its being exhauſted by the Sun and Weather, and being continued within it, preyed upon, putrified and deſtroyed the hearty ſound Wood. As to the Wood that had not been painted, the Sun and Weather conſumed and exhauſted its Sap, and thereby rendered it of a proper Conſiſtence, and made it well ſeaſoned. It is for this Reaſon I adviſe againſt painting, or otherwiſe encruſting ſappy green Wood, unleſs you have ſome very powerful Reaſons for it.

I once happened in Company with a very ingenious Gentleman, one Mr. *Smith*, who was ſo kind as to communicate a Secret to me, which ſtruck me greatly, and I inſtantly put it in Practice, and am now convinced it is an excellent Method to make red Fir Timber near as durable as Oak, *i. e.* After your Work is tried up or even put together, lay it on the Ground with Stones or Bricks under it to about a Foot high, and burn Wood (which is the beſt firing for that Purpoſe) under it, till you thoroughly heat and even ſcorch it all over, then, whilſt the Wood is hot, rub it over plentifully with Linſeed-oil and Tar in equal Parts, and well boiled together, and let it be kept boiling whilſt you are uſing it; and this will immediately ſtrike and ſink (if the Wood be tolerably ſeaſoned) one Inch or more into the Wood, cloſe all the Pores, and make it become exceeding hard and durable, either under or over Water; and if there ſhould be any ſappy Parts in it, they will receive ſuch benefit by the Fire and Heat of this natural and penetrating Liquid, that they will alſo thereby become exceeding durable. Good red Fir prepared after this Manner, will for many Uſes laſt as long, if not longer even than Oak Timber, eſpecially in Water; and if good Fir Timber is conſtantly kept in Water, it will keep freſh and ſound much longer than Oak.

I have often ſeen ſlating and plaiſtering Laths, clove out of Bog Oak and Bog Fir; in cleaving the Fir Laths, I frequently obſerved the Turpentine as freſh and firm in it as if it were perfect Roſin; and I have heard of the Splinters of this Wood being uſed not only for Torches, but by poor People ſometimes as Candles. In the Butt of a clean Trunk of a Bog Fir-tree, it will ſplit thin and tough

like

like Whale-bone. It is a generally-received Notion that the Timber Trees which are found in ſuch Abundance in ſome of our Bogs, have lain there ever ſince the great Deluge, but be that as it may, the Bog Oak Timber is always found to be fruſhey, dozed and ſhort grained, and not near ſo ſound as the Fir Timber, tho' both taken up at the ſame Time out of the ſame Bog. Hence I think we may ſafely conclude, that red Fir Timber is exceeding durable, and conſequently unexceptionable as to our preſent Purpoſe, provided it be kept entirely under Water; therefore, let us determine to make our Coffers of good ſound red Fir Timber, and keep them under Water as much as we conveniently can.

SECT. II.

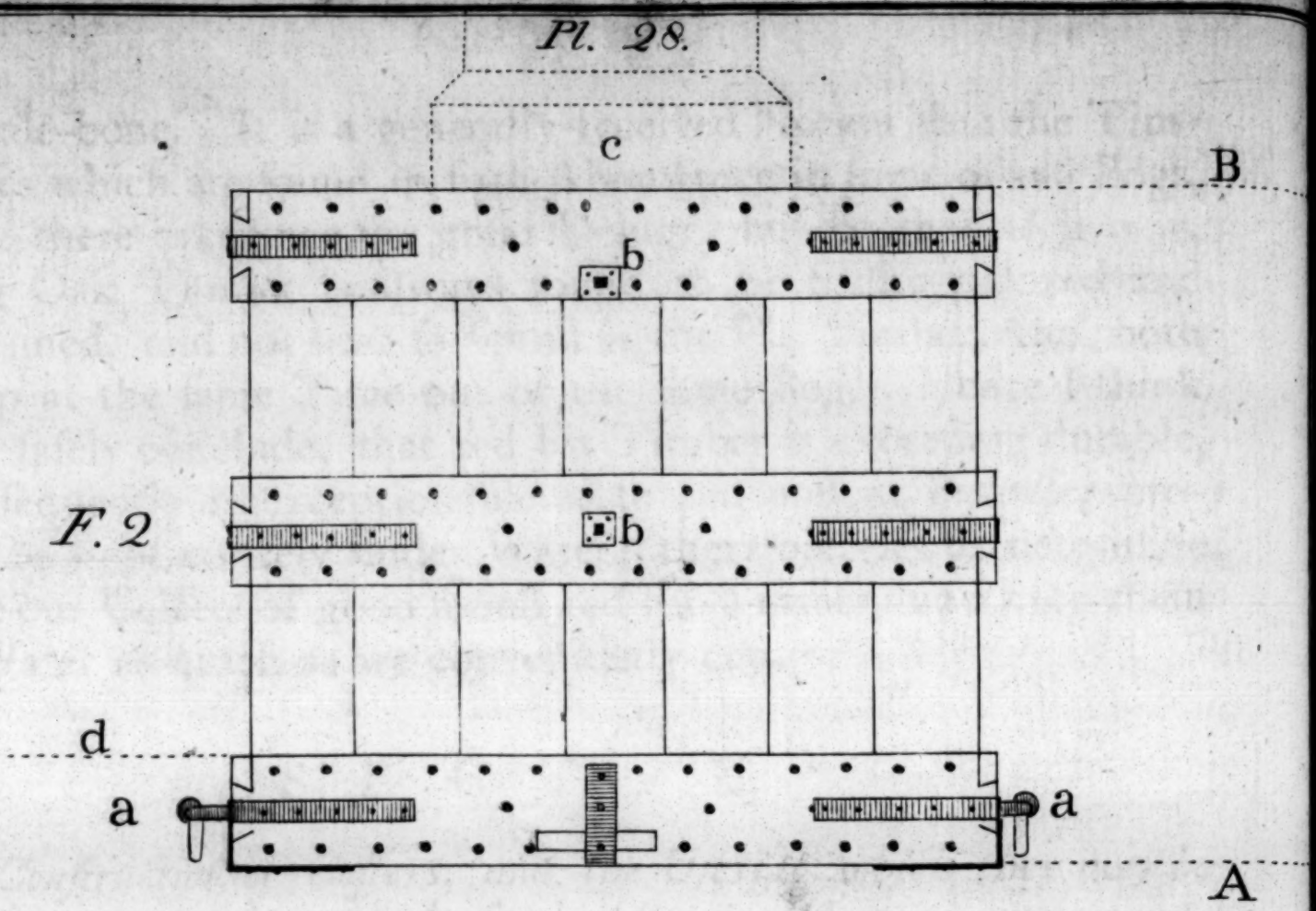
Of the Conſtruction of Coffers, and the Uſes to which they may be properly applied, for building in Water.

BEFORE we can fix upon the Conſtructions of the Coffers, we muſt have ſome Particulars propoſed, becauſe that which might anſwer for one Purpoſe, might not anſwer for another: I intend, therefore, as briefly as poſſible to ſhew ſome of the Uſes to which they may be applied. And you may be aſſured, I ſhall leave you Room enough to exert your own Genius, by adopting them to other Purpoſes.

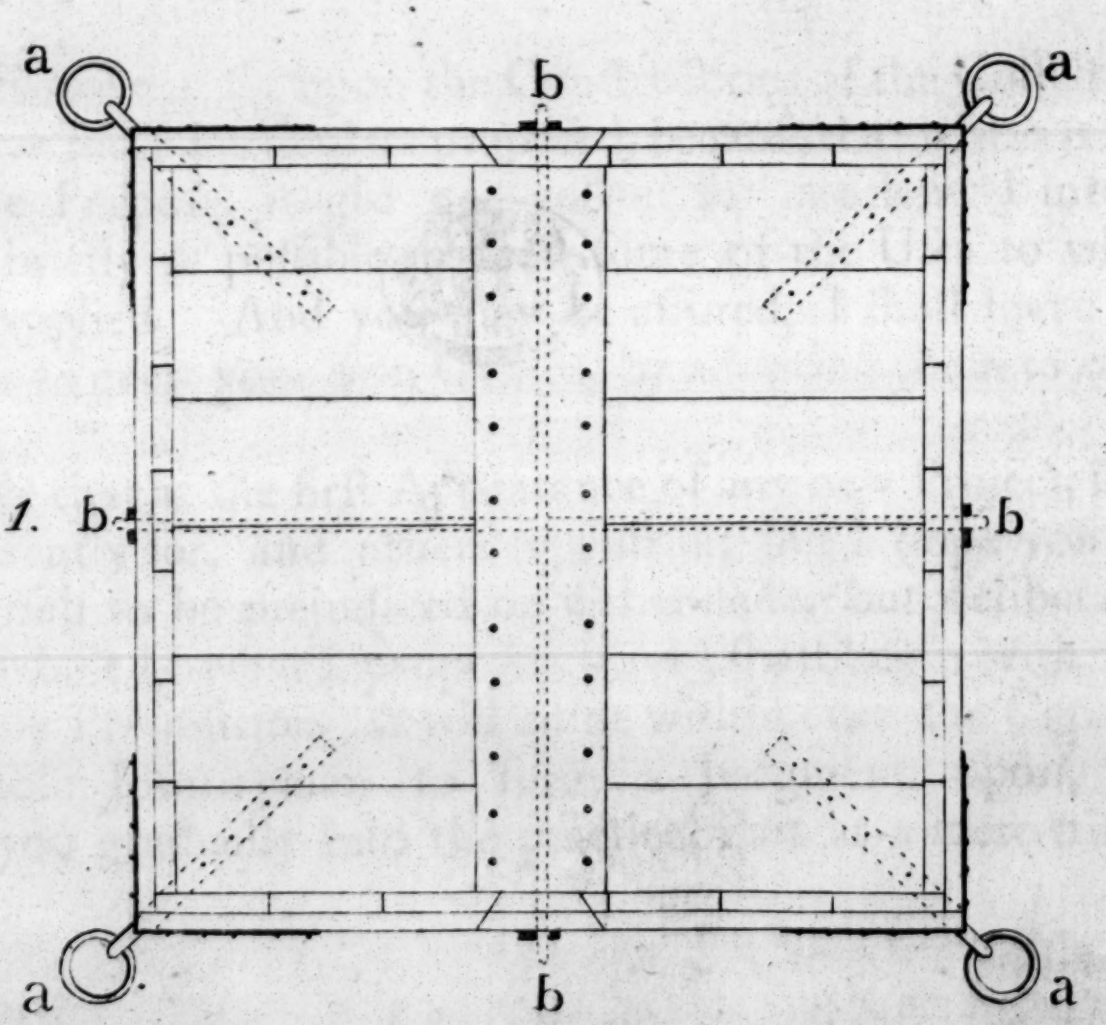
I am ſenſible that at the firſt Appearance of any new Project, ſome may be vehemently for, and others againſt it; but I hope you will not ſuffer yourſelf to be prejudiced on either Side, but deliberately examine the whole of what I propoſe. And I ſhall begin with ſuch a plain and eaſy Propoſition, as will come within even the Capacity of any ſenſible Journeyman to form a Judgment upon, and thereby lead you gradually into the practical Part at a mere trifling Expence.

PROP.

Pl. 28.



F. 2



F. 1.

PROP. I. *A Gentleman has a Baſon of Water in his Garden, he requires a ſure, quick and cheap Foundation to be laid therein, ſufficient to ſuſtain a Statue of Lead, on a Stone Pedeſtal, the Plinth of which is three Feet ſquare, the Water ſix Feet deep.*

METHOD *laid down in* PLATE XXVIII. *Scale* 2 *Feet* 1 *Inch.*

Fig. 1. Repreſents the Plan or Bottom of the Coffer, which is to be made of only Inch and half Plank, which you ſee will require ſix Planks of about ſix and a half Feet long each, and in the Middle acroſs them, there is to be a Ledge nailed on with Dog-nails, and dovetailed at each End into the oppoſite Sides, and all the Bottom and upright Planks are to be dovetailed together alſo.

Fig. 2. Shews you the Elevation or out-ſide thereof, in which you ſee there are ſeven Planks placed erect, with three Belts ſurrounding the whole, and they alſo are to be dovetailed at the Angles, and ſtrapped with Iron: Each of the four lower Straps, a. are to have a third Plate turning down, and nailed in a diagonal Manner on the Bottom, which you ſee dotted out, and each of the four Squares are to have a ſtrong projecting Neck, through the Ends of which there are to be either Rings or Holes, to run Ropes through them, each of which Ropes is to be at leaſt three Times the Depth of the Water, that you may the eaſier manage it in the launching and fixing it in its Birth: Each of theſe Ropes is to be doubled together, and fixed to a Wooden-block to buoy them up, which you may throw into the Coffer till you want them. In this Fig. 2. A. is the Bottom of the Water. B. Is the Surface. b. Brace Bars, and c. the Plinth of the Pedeſtal, which will ſeem to ſtand on the Surface of the Water; for you may remember that we reſolved to keep all our Wood within the Water. d. Bank or filling to preſerve the Lime-water.---Having thus fully conſidered the Conſtruction of the Coffer, let us conſider the Nature of the Foundation that is to be laid in it, *i. e.* the Stuffing, which is to make it a ſolid and a ſubſtantial Foundation for the Pedeſtal.

SECT.

SECT. III.

Of ſtuffing the Coffers and Petrifications, laid down and to be conſidered as general Concluſions.

THE Word *Coffer* is borrowed from *Palladio*, we ſhall borrow the Word *ſtuffing* from *Alberti*, who has treated largely upon it; and ſtrictly obſerve, that before the Coffer is launched, you are to be provided with ſufficient Quantities of very ſmall Stones, clean and ſharp ſandy Gravel, and Roach-lime ready at the Kiln whenever it is called for; and with theſe Materials you are to fill or ſtuff the Coffer, ſo that the whole may be juſtly proportioned and ſtuffed as ſolid and as compact as poſſible.

In order to learn the true Proportions and Quantities of the ſtuffing, I made the following Experiment. I had a Box made of one exact cubical Foot, which held 200 Stones fit for the Purpoſe, each Stone on an Average, weighing about ſeven or eight Ounces, the whole conſequently weighed 90lb. nearly. The ſame Box held about 80lb. of tolerably dry, ſharp and rather fine ſandy Gravel, without any ſort of Stones, except thoſe ſmall ones which are uſually among Sand. Part of thoſe Stones I put again into the Box in thin Layers, filling all the Interſtices or Vacancies with the Sand, and after that Manner it contained 80lb. of the Stones, and 40lb. of the Sand, and I know it would alſo have held the proportionable Complement of Roach-lime, that is 10lb. made liquid as before treated of, which together gives the juſt Quantities and Proportions of 10, 40 and 80, or 1, 4 and 8, which will be much eaſier remembered, and muſt be ſtrictly obſerved; and to this Purpoſe, you muſt depend on ſome careful and faithful Rough-maſon or Bricklayer. And alſo, pleaſe hence to obſerve, that one cubical Foot of this ſtuffing will weigh 130lb. which is nearly the ſame Weight of one ſolid Foot of *Portland* Stone.

There are three different Methods for making uſe of the Lime in ſuch Work as this; one is, to mix the Roach-lime made liquid, with its Proportion of Sand and ſmall Stones in ſuch Manner, as

may

may cloath every Stone and Particle of Sand with it. The ſecond, to ſlack and turn them all up together like Mortar. The third, to lay each of the three, as it were, in very thin Layers, ſtill obſerving the ſame Proportion, take which of theſe Methods you pleaſe, provided the Roach-lime be, however, carefully and judiciouſly mixed with the Stones and Sand, for if theſe Materials are not equally mixed, how can you expect them to petrify and unite into one ſolid Maſs? But if they are properly mixed together, the whole ſtuffing of this Coffer, will actually petrify, and become one ſolid and compact Subſtance, as hard and as cloſely united together as if the ſame was in one Block or Rock, and it will be many hundreds of Years before the Coffer (being in Water) will be in the leaſt decayed.

I have ſome other Cautions to give you concerning the ſmall Stones you are to make uſe of. Let none of them exceed an Handful, or one Pound Weight, as before mentioned; and if you can conveniently, let them all be Lime-ſtone, broke into Stones of about that ſize, carefully preſerving the very duſt and leaſt Scrap of them for Uſe.

I before declined touching on Petrifactions, and I now ſuppoſe that you do admit that there is a petrifying Quality both in Lime and in Lime-water, and there are inconteſtible Proofs of this petrifying Quality being in Lime-ſtone, even without Calcination. As for Inſtance, Doctor *Thomas Molyneux* ſays in his *Natural Hiſtory of* Ireland, Page 184.---" There was one Urn found in " a little ſandy Hill, near *Cooks-town*, on the Road to *Liſſon*, in " the County of *Tyrone*, it was covered with a great rude Lime- " ſtone, which being removed in order to make Lime, the Urn " was diſcovered in a Hole encompaſſed with ſix Stones of equal " Bigneſs, which made a Hexagon, in which the Urn ſtood. The " Water that had fallen on the Urn from the Lime-ſtone, or the " Air condenſing, had petrified and made a Stone-cruſt on the " outſide thereof." And further obſerve, that if the poor ſcanty Pittance of that petrifying Quality, that ſoaked from the Lime of the Piers of *Eſſex-Bridge* into the Bed of Gravel, that was on all Sides open and expoſed to the Rapidity of the Water, had ſo

 powerful

powerful an Effect as before-mentioned; we may certainly conclude, that pure Lime-water will petrify ſharp Sand, but cannot make it cement. And the ſtuffing of theſe Coffers, will actually petrify alſo, (particularly if they are done in the Manner above-mentioned) and that in a much ſhorter Term than may, perhaps, be expected. If you ſearch among the *Roman* or antient Hiſtorians, you may find numerous Accounts confirming the petrifying Qualities of theſe three Materials, when they are mixed together: And beſides thoſe I have already furniſhed you with, conſult *Chambers*'s Dictionary, under the Article ROAD, and read *F. Meneſtrier*'s Obſervation, which I ſhall give you in its proper Place.

As I have deſired you to preſerve and uſe even the Powder, or ſmalleſt Fragments of the Lime-ſtone, I ſhall here aſſign my Reaſon for it, which is, that the Powder of freſh quarried Lime-ſtone, (which you will find to have a ſulphureous ſmell, partaking greatly of the ſmell of Gunpowder) has this petrifying Quality to a very high Degree, and that Calcination heightens that Quality, is univerſally agreed to; but yet it does not operate in that Manner, uſed alone. For inſtance, if Lime be left to lie by itſelf, either on Land or in Water for thouſands of Years, it would neither petrify nor come to any Degree of Hardneſs, nor would Sand alone petrify; but when theſe two unite, they begin to operate powerfully upon one another.

In order to come at a thorough Knowledge of this petrifying Quality, I would recommend the following Experiment: Take ten Pounds of Lime-ſtone freſh quarried, pound it into very fine Powder, and take the like Quantity of ſharp, clean and fine Sand; get thoroughly burnt Roach-lime hot from the Kiln, the like Quantity; put it in a Veſſel and pour Water upon it leiſurely, and ſtir it gently till you find it is all diſſolved, and as it were melted into a hot Liquid; rub and thoroughly mix the Flour of Lime-ſtone with the Sand, and without letting that Lime-liquid have Time either to cool or evaporate, ſtir in and moſt effectually mix and work them all together very ſtiff, and beat them thoroughly on a clean boarded Floor, and then make this Mortar into Blocks, about the Size of a Brick; bury one of theſe Blocks in very damp or wet Ground,

Ground, put another entirely in Water, and keep a third in ſome dry Place: Now I am confident, that each of theſe Blocks will in a reaſonable Time actually petrify into Stone, and become as much ſo as if they had been cut or wrought out of a Rock, and that they will endure Calcination, and become good Lime afterwards, but not ſo rich as that was from whence they derived: And with reſpect to Time, that which is depoſited in the Bowels of its own natural Mother, will grow the firſt into Stone; that laid in the Water, will be the ſecond, and that which is kept in the dry Place, will be the laſt and of a ſhort brittle Nature: But the firſt, if in a large Block, will not only become hard, but ſtout and ſtubborn, and would ſtand and give great Reſiſtance to a Hammer or Punch: The ſecond, would be more free: And the third, fly off ſhort. I apprehend that this little Experiment is worthy of Attention, becauſe, by aſcertaining the Time of theſe Depoſits, and trying the Blocks from Time to Time afterward with a Tool or the Point of a Penknife, ſome uſeful Knowledge might be obtained; but be that as it may, theſe are ſome of my Reaſons for recommending Lime-ſtone. However, where that cannot be conveniently got, you muſt make uſe of ſuch hard Stones as you can get, but be ſure you have them broke to the Sizes above-mentioned, for ſuch will moſt aſſuredly cement and unite together with the Lime and Gravel, and each of the Stones will contribute to ſuſtain the Confidence repoſed in them; whereas, if one large Stone was put in among them, it would not unite but ſtand up ſtiff, and thereby be a great Means of ſhifting the Weight from itſelf, and throwing it on the ſmall Stones that ſurround it, and conſequently would overturn inſtead of ſupporting the Weight which it was deſtined to bear. For theſe, therefore, and many other Reaſons, I moſt earneſtly recommend it to your Practice, to uſe no other but ſmall Stones in your ſtuffing.

You are alſo to take particular Care, that your ſandy Gravel is ſharp and clean, and of that Degree of Fineneſs as may contribute proportionably to the Solidity of the whole, and not to throw your Stones in one Place, and your Lime and Sand in another, but let them be all equally mixed throughout the Work, and all this can

be eaſily done; for let the Water be of what Depth it will, or your hurry ever ſo great, this you may do, and you are not to neglect it. And obſerve alſo, that this ſort of Work can be much more effectually done in Water, than upon dry Land, even admitting that it was to be done with wet Grout, becauſe theſe three Materials being thrown in proportionably together, each Stone and every Particle of the Gravel and Sand, will take Poſſeſſion of a Place ſuitable to it; but the Sand in particular, will continue in quick Motion till it finds out a place of reſt proportionable to its Size, and inſtantly fill up the moſt minute Vacancy, (provided that you obſerve theſe Directions properly) and immediately become as compact and as ſolid as a Bank of a Gravel-pit that has been formed by Nature.

But after all I have ſaid, you may, perhaps, imagine that this ſtuffing, even ſo managed, will not be ſufficient for our preſent Purpoſe, without giving it a long Time to ſettle and cement; and I grant it would not be amiſs to allow it ſome ſhort Time, to give the finer Parts of the ſtuffing Time to ſubſide, ſupplying it with theſe finer Parts, till it will receive no more; and if theſe hard and ſubſtantial Materials are made ſolid and compact, and cloſely confined together, how can they ſettle or prove inſufficient even before they are cemented? Now I aſk you, do you believe, or did you ever hear any experienced Man ſay, that cloſe gravelly Ground was not a ſubſtantial Foundation? And is not this in all Reſpects, at leaſt equal to it? Becauſe, it is actually Stone reſting upon Stone, of different Sizes down to the minuteſt Particle of Sand all compacted together into one ſolid Maſs. *Palladio* has furniſhed you with his Opinion in the tenth Page, and ſays, "You ſhould chooſe "a Place where the Bed or Bottom is even and uniform, and is "either of Stone or of Gravel, becauſe Stone or Gravel are excel-"lent Foundations in Water." And herein lies the grand Advantage that will attend all theſe Projects, *i. e.* they are to be executed in Water, and if we ſupply the Water with due Proportions of this ſtuffing judiciouſly, it will take great Part of the trouble from us, and will, as it were, diſpoſe of every Particle of the fineſt Sand, and with incredible Expedition convey it into ſuch Interſtices and

ſmall

ſmall Pores, as it will find fit to receive it, and if it does not fit or get room in one Place, it will inſtantly conduct it downwards by its own Gravity, till it gets it properly ſettled, which I preſume, no human Art could ſo effectually accompliſh; and I think it alſo adviſable to propoſe the following Experiment.

When this little ſlight Coffer is made and ſtuffed with wet Grout, to within five or ſix Inches of the Top, level it ſo that every Stone on the Surface, may come to a proper and equal bearing, and cover it all over with a Coat of Grout; expoſe it then to the View of judicious Perſons, and get their Opinion of it, and then Floor it all over with cut Stone, after a Workman-like Manner: It will then effectually ſuſtain the Weight of the Statue, which in this Caſe is the Thing required; but in order to ſum up and finally determine the Utility of theſe Speculations, which are in a large Degree the Baſe and Foundations of the following Propoſitions; let us particularly recollect, examine and conſider well, what *Alberti* has tranſmitted down to us; that is, " Upon pulling " down a very high and ſtrong Tower at *Bologna*, they diſcovered " that the Foundations were filled with nothing but round Stones " and Chalk to the Height of nine Feet."

Let me, therefore, recommend it to you, to get a ſquare Pit dug, ſuppoſe of 9 Feet deep and as many broad, the Length at Diſcretion, and let that be done near a Pump, or convenient to ſome Water, and when it is filling with theſe Stones and ſandy Gravel, ſupply it moſt plentifully with Water, to convey the Sand into all the Vacancies, but put neither Lime nor Lime-water in it, and when it is filled level to the Surface, throw more Sand and plenty of Water over it, and let the Men (with the back of their Shovel) beat down all irregular Stones, and make an even Surface as before mentioned, but do not then Floor it with cut Stone, but get ſome Gentlemen or other ſkilful Perſons to view, to prove and examine whether or no that is a ſubſtantial Foundation, whereon to erect the moſt weighty Building immediately. And if it be given in the Affirmative, as moſt certainly it will, then conſider alſo, that if the Lime or Lime-water was properly compounded with thoſe materials, then would the whole be endued with this great and remarkable

Advan-

Advantage, *viz.* The longer it will ſtand, the harder and more durable it will grow; and if the Pit was a Mile Cube and ſtuffed in like Manner, it would be all the ſame in effect.

SECT. IV.

Concerning two other more weighty Purpoſes to which theſe Methods may be applied in ſtill Water.

PROP. II. *LET us ſuppoſe that a Gentleman has an elegant Viſto, terminated by a ſpacious Canal, the Water in which is twelve Feet deep, and he requires a Foundation to be laid in it, whereon he intends to erect an Obeliſk of* 36 *Feet high.*

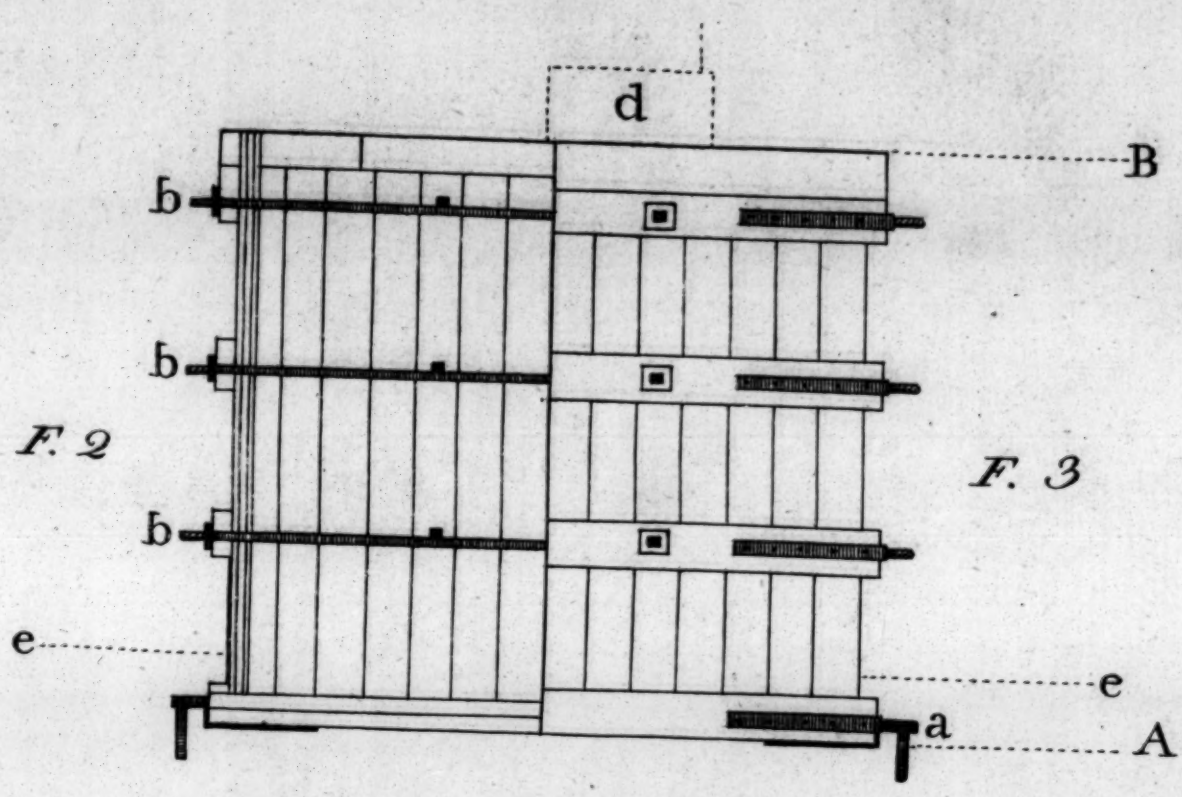
METHOD *laid down in* PLATE XXIX. *Scale* 5 *Feet* 1 *Inch.*

Wherein note, Fig. 1. Half of the Plan or Bottom of the Coffer, which is to be made of four or five Inch Plank. Fig. 2. Half of the Section. Fig. 3. Half of the outſide erect, dovetailed and ſurrounded with 5 Belts, and Fig. 4. Half of the Platform which is floored with cut Stones of 4 by 2 Feet, and a Foot thick. a. The Rings for Hauling and fixing the Coffer. b. Brace Bars, Chains or Beams as moſt convenient. c. Scite of the Obeliſk. d. Plinth of the Pedeſtal. e. Bank to confine the Lime-water.

Let us alſo ſuppoſe, that a Nobleman hath a large Piece of Water adjoining his Pleaſure-garden, from a particular Place in which, he and his Company have frequently been highly delighted with beholding ſeveral beautiful Proſpects, from his Pleaſure-boat; and he has a very public Spirit, and is deſirous to enlarge the general Beauty of that highly improved Country, the better to enjoy the Benefit of the wholſome Air, he is determined to have an elegant octagonal Pavilion or Pleaſure-houſe of 18 Feet Diameter, built in that particular Place; that the reſpective Windows may take in the Views of the natural Landſcapes: And he alſo apprehends, that when the Windows are fully illuminated, a Band of

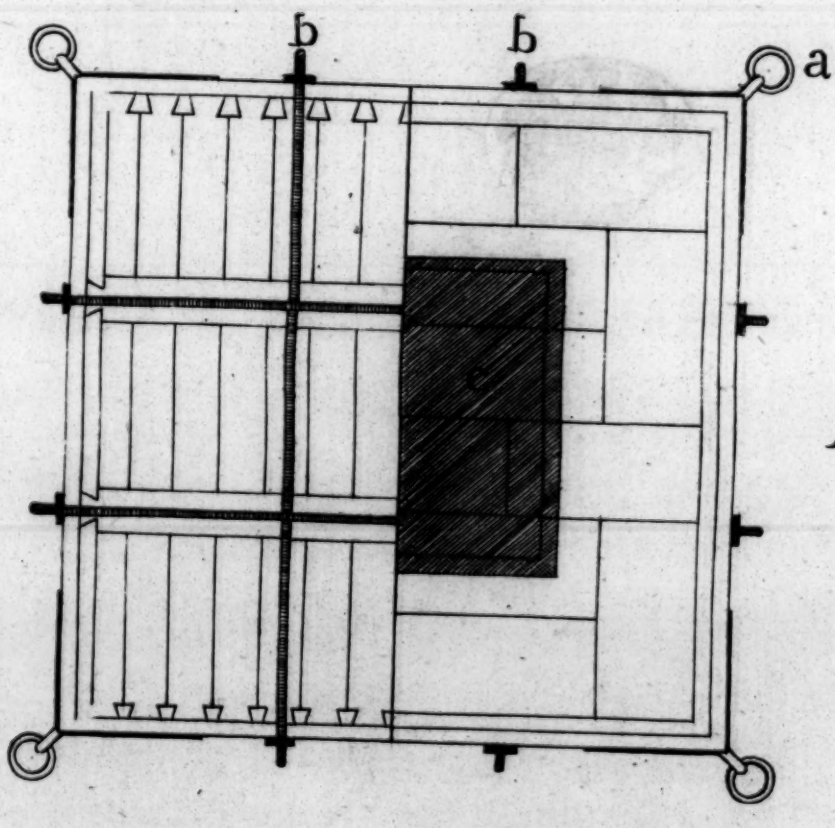
Martial

Pl. 29.



F. 2

F. 3

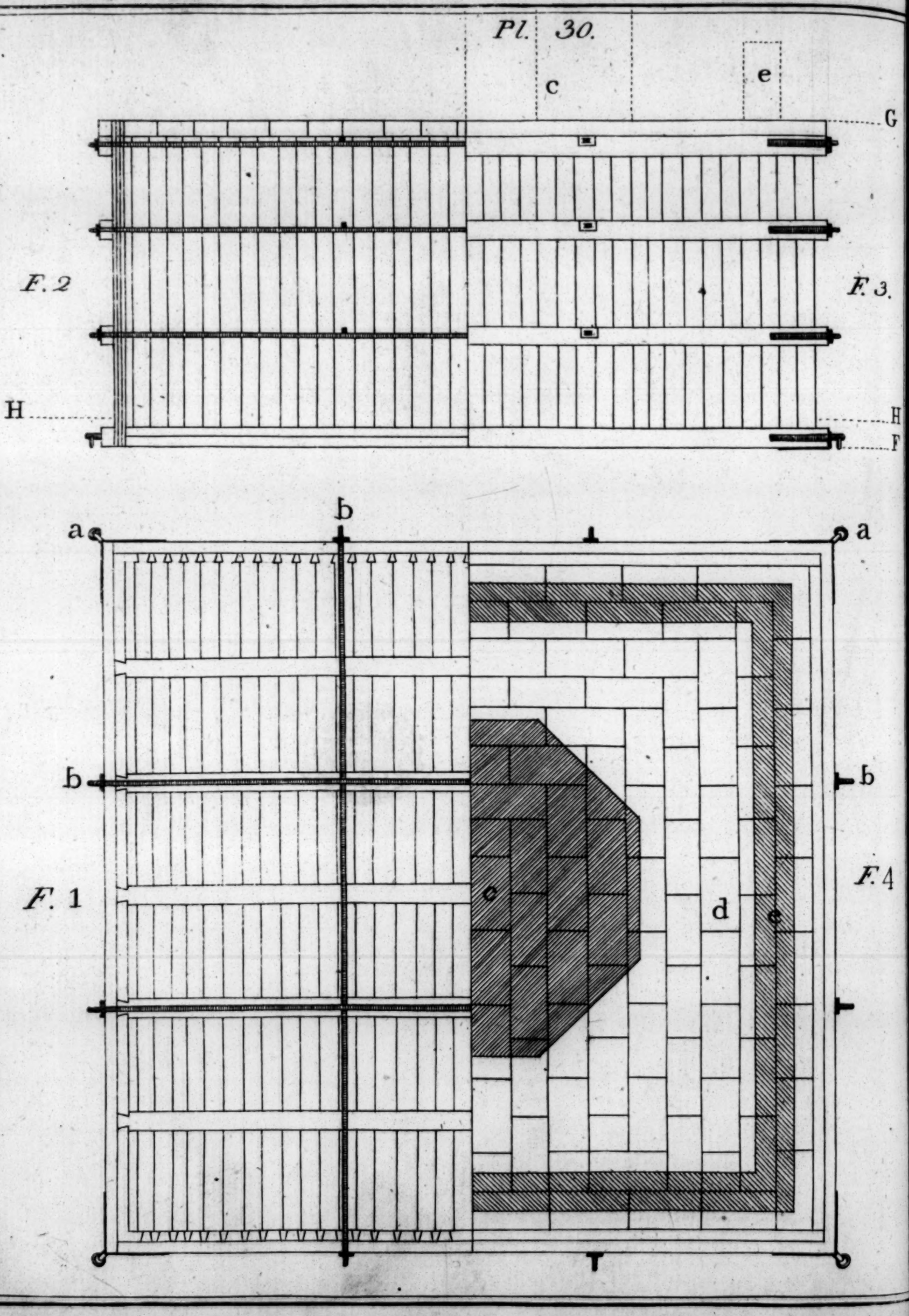


F. 1

F. 4



Pl. 30.



Martial Muſic, *&c.* on rejoicing Nights, will contribute greatly toward the Amuſement of the Nobility, and the adjacent Neighbourhood. Therefore,

PROP. III. *You are required to build a Pavilion of cut Stone, in a Lake of freſh Water eighteen Feet deep; the Platform to be encloſed with a Parapet of the ſame, extending* 34 *Feet ſquare.*

METHOD *laid down in* PLATE XXX. *Scale* 8 *Feet* 1 *Inch.*

Fig. 1. Is the Plan or Bottom of one half of the Coffer. Fig. 2. Section or inſide of the ſame as if it were floored with cut Stones. Fig. 3. Elevation thereof. F. Bottom of the Water. G. Surface of the ſame. H. The Bank, and Fig. 4. The Platform floored with cut Stone of one Foot thick. Wherein note, a. Launching and hauling Rings. b. Repreſents the Situation of the Brace-bars, which in this Work ought to be much rather ſmall Boom-chains, and Brace-beams alternately. c. Scite of half of the Pavilion. d. Walk, round the ſame. e. Parapet-wall.

This Coffer is to be ſurrounded with a double Belt above, and three ſingle Belts below them, as in the laſt Proportion; and they are to be dovetailed and plaited with half flat Bar-iron. All theſe Belts are to be both bolted or ſpiked to the Hull or upright Piles, and alſo pinned with Oak Trundles of about $\frac{3}{4}$ Inch Diameter, which are to be driven in the outſide, and wedged within-ſide. Both the upright Piles of the Hull, and all the Belts, you may ſee by the Scale, are to be ſix Inches thick. The ſtuffing the ſame as before directed, and to prevent Repetition, I ſhall omit ſeveral other Matters, which you ſhall be made fully acquainted with, through the Progreſs of the following explanatory Notes, which you are to apply according to your own Judgment. Let us now endeavour to point out another Method of working in Water, for inſtance, in freſh Water Rivers.

CHAP.

CHAP. XV.

Concerning another Method for laying of the Foundations for the Piers of Stone Bridges, in large and deep Rivers.

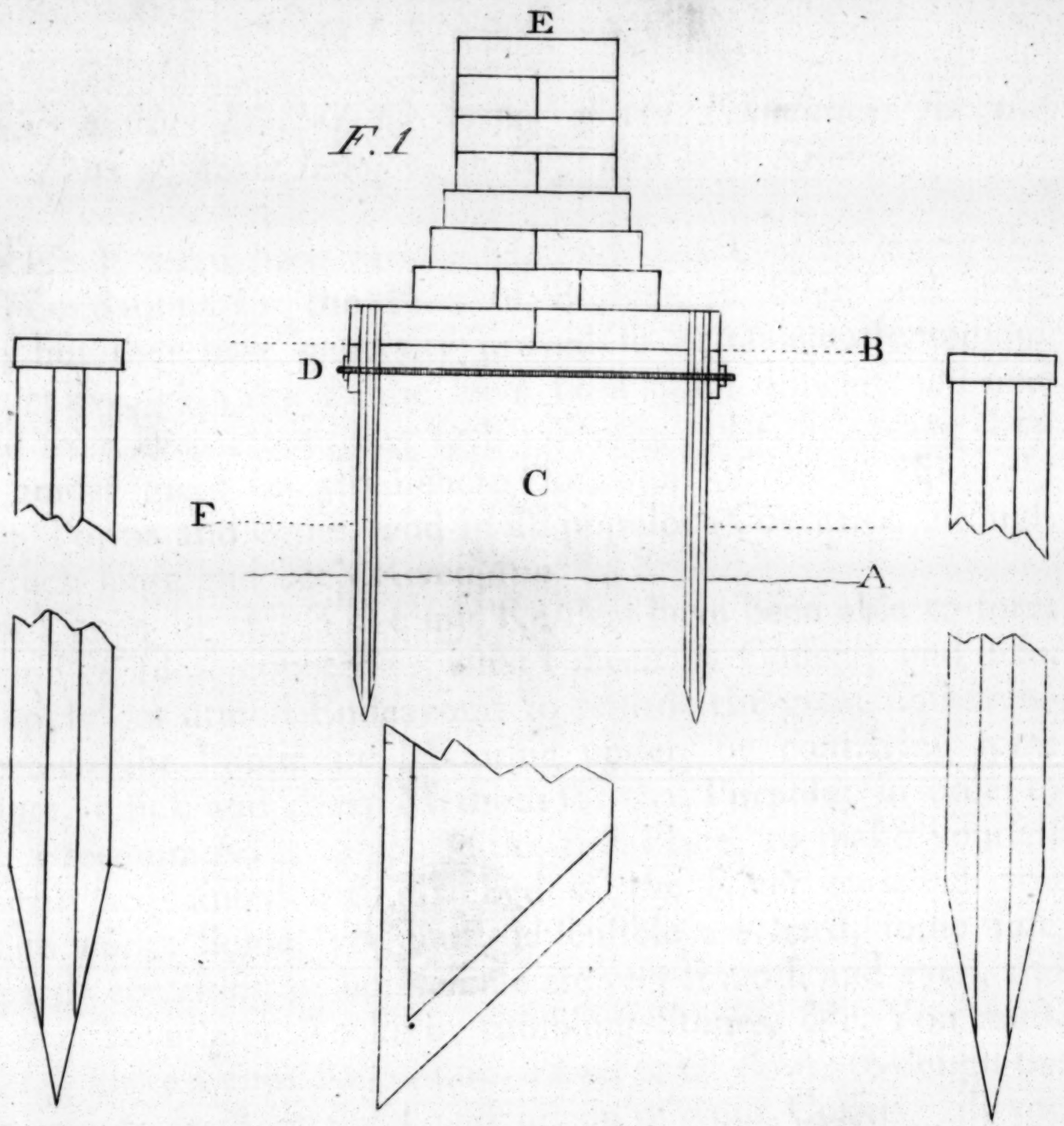
THERE have been various Methods practiſed in laying the Foundations for the Piers of Bridges, in large and deep Rivers; but they have generally proved ſo extravagantly tedious and expenſive, that the Public have been quite diſheartened and deterred from even attempting ſuch a Work, notwithſtanding they labour under great Inconveniencies for want of them, eſpecially in large Towns and Cities, and in all populous Countries, through which ſuch large and deep Rivers run.

Now I hope by this Time my Readers have been able to form ſome kind of Idea, concerning what I mean by Coffers; and if ſo, let us apply our utmoſt Endeavours to remedy the great Diſadvantages which the Public are labouring under, by contriving ſome other ſure, quick and cheap Methods for that Purpoſe; in order to which, I recommend it to you in the firſt Place, to make yourſelf thoroughly acquainted with the Bed of the River on which you intend to work: Some, you muſt be ſenſible are hard, ſome ſoft, ſome partly conſiſting of both, ſome are very ſmooth and even, and others may have large Rocks or tumbling Stones, *&c.* You muſt, therefore, make a firm Reſolution, never to ſit down to deſign the Bridge, nor to conſider the Conſtruction of your Coffers, till you have moſt carefully tried, and ſearched diligently into the Bed of the River, which you may eaſily do by the Methods formerly directed, let the Depth of the Water be what it will in Moderation: And when you have collected and figured down your Soundings and Borings, you may proceed, and conſider the groſs Dimenſions of the Bridge, and the Conſtructions of your Coffers.

But I preſume, we may venture to eſtabliſh one general Rule, concerning Bridges in particular: *i. e.* To proportion the Bridge to the Depth of the Water; as for inſtance, if the Water be three Fathom deep, your Coffer muſt be 19 Feet high, and at leaſt 18 Feet

Pl. 31.

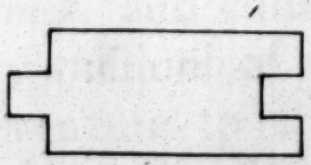
F. 1



F. 2



F. 3



F. 4



Feet broad in the clear, and it will ſtand as firm as a Cube. And you muſt adhere cloſely to *Palladio*'s Rule, which is, " that the " Foundation muſt be as thick again, as the Wall intended to be " raiſed upon it;" but you muſt by no Means follow his next Direction, *i. e.* " to make the Foundation wider in ſoft looſe " Ground," for that would make the Bridge quite prepoſterous; but you muſt ſtrengthen the ſoft Ground with Piles to ſuch a Degree, as may bring it to an Equality with the reſt of it, (as I did at the two northerly Piers of *Eſſex-bridge*, ſee Plate XIV.) I ſay, if the Water is 18 Feet deep, your Coffer muſt be at leaſt 18 Feet broad, and conſequently the Pier 9 Feet thick; which (if executed as repreſented in Plate XV. Fig. 1, 2 and 3,) will admit of an Arch of 54 Feet Span; and it is my Opinion (with Submiſſion to ſome eminent Gentlemen) that the Breadth of a Bridge ſhould be determined by its Heighth alone, or that the whole Bridge taken together, muſt bear ſome Analogy to the Depth of the River; for the higher the Superſtructure, the greater extent the Foundation requires; but as there are numerous Books extant on this Subject, you may conſult them, and let us keep to our Text with reſpect to the Foundations of Piers, and on this Subject as before, we ſhall begin in ſhallow Water.

SECT. I.

PROP. IV. *IT is required to build the Piers of a Stone Bridge, in a freſh Water River of one Fathom deep; the Bed of the River, Loam or ſharp and clean ſandy Gravel: The Proportions of the Bridge left to Diſcretion.* See another different

METHOD *laid down in* PLATE XXXI. *Fig.* 1. (*laid down by a Scale of* 5 *Feet* 1 *Inch.*)

Repreſents the Section of the Coffer, and the Pier ſpringing high, as if the Foundation had actually been laid. Wherein note, A. Bed of the River. B. Ordinary low Water in Summer. C. Conſtruction of the Coffer, which is to hold the Stuffing, as for-

merly directed. D. One of the Brace Bars, which may be an Inch and a half ſquare. E. Shews the Bond of the Cut-ſtone-work of the Pier; and F. the banking.

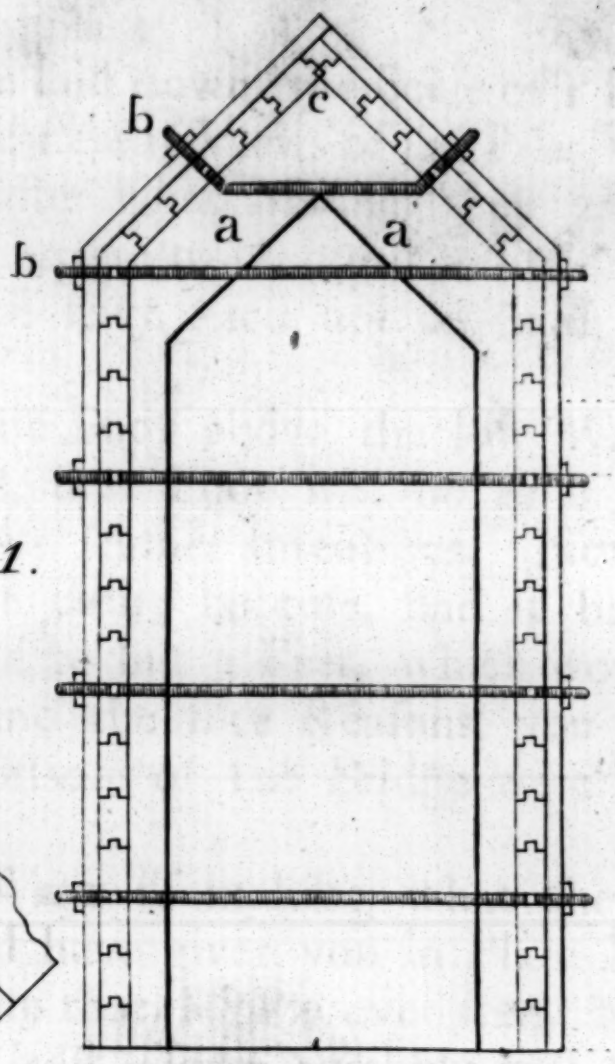
Fig. 2, 3 and 4, are laid down by a Scale of 1 Foot 1 Inch, and exhibits the Plans and different Views of the Piles, that are to compoſe the Coffer, and after what Manner they are to be pointed, which may, perhaps, require to be burnt a little in the Fire; but in theſe Kinds of Beds they need not be ſhod or pointed with Iron.

This Coffer riſes one Foot above the low Water in Summer; but generally ſpeaking, that Foot will be as if it was all under Water, according to our former Intentions. Now, the Coffer is eight Feet wide in the clear; becauſe, had it been made exactly cubical, the Pier would be but 3 Feet, which would be too diminutive; and for this and the like Reaſons, you were not to be confined, as the Proportions of the Bridge were left to your own Diſcretion.

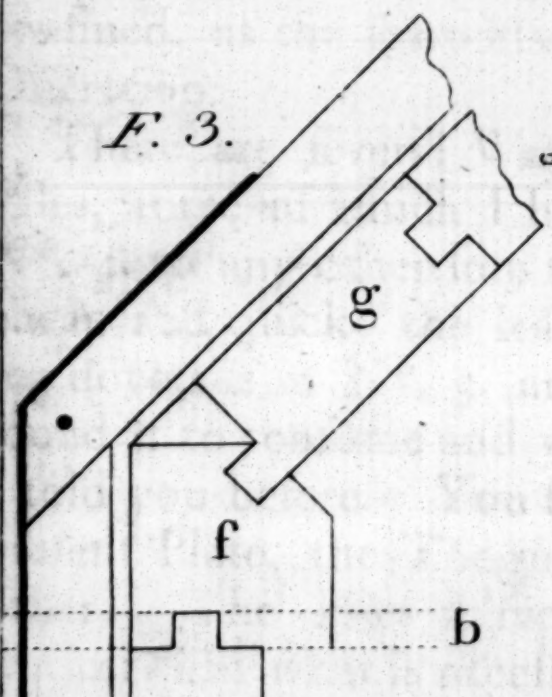
There are ſeveral Ways of making what they call dovetailed Piles, three of which I have given you in Plate XV. but I prefer N°. 4. to any other ſort that I have ever ſeen, becauſe it is ſure, cheap and quick: the leaſt gravelly Pebble will tear and ſplit off the dovetails in N°. 5. and N°. 6. I uſed at *Eſſex-bridge*; but I found it to conſume and waſte a vaſt deal of Timber and Time, as I told you before. You ſee in N°. 4. or in Fig. 2, 3 and 4, in the preſent Plate, the Tongue of one Pile falls into the Groove of the other. The Piles I ſuppoſe to be 12 by 6 Inches, which is thicker than what is neceſſary for this little Coffer; but if a ſlender Pile would meet with ſtiff Ground, it would not drive, and theſe will be pretty ſtout to bear a proportionable Force. The 6 Inches thick are divided into three Parts, two Quarters, that is Scantling of near two Inches ſquare, forms the Groove, and another of the ſame Size makes the Tongue, and are all put on with proportionable Spikes, Pins or Brads. Their Connexion will be more fully exhibited by the next Plate.---Plate XXXII. Fig. 1. *Scale* 5 *Feet to* 1 *Inch.* Which is the Plan of that half of the Coffer that lies to the Stream, but the Stern of the Coffer may be about two Feet longer. The

Line

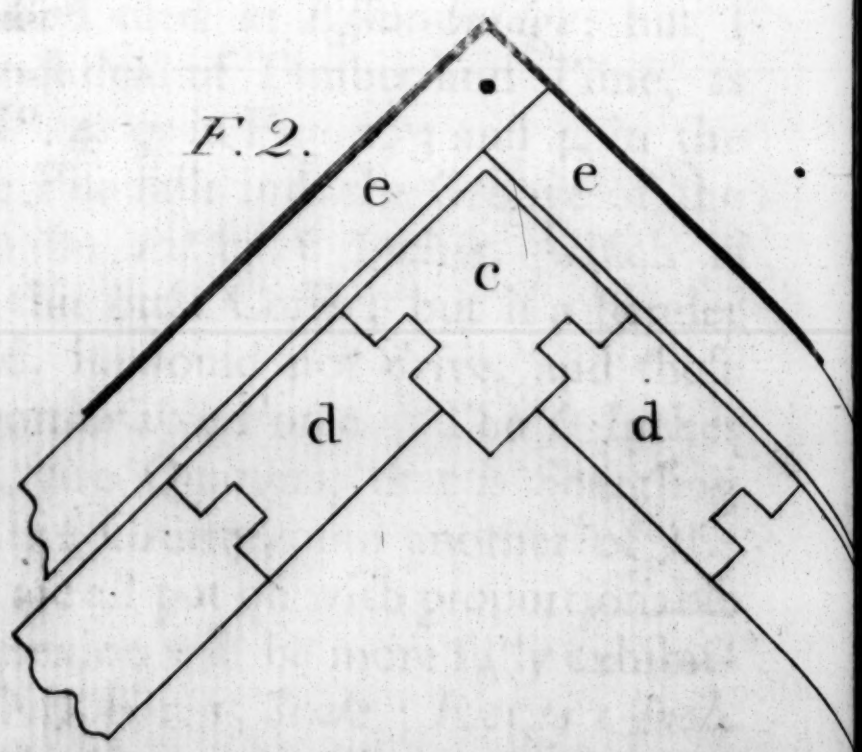
Pl. 32.



F. 1.



F. 3.



F. 2.

Line a. ſhews what Proportion of the Coffer the firſt Courſe of the cut Stone is to occupy. b. the Brace Bars.

Fig. 2. laid down by a Scale of 1 Foot 1 Inch. Wherein note, that c. repreſents the Cut-water Pile. d. The Piles of the Coffer. e. The Belt that incloſes them, which is to be dovetailed at every Angle, and plated with half flat Bar Iron.

Fig. 3. by the ſame Scale. f. The corner Pile at the obtuſe Angle. g. The Piles of the Coffer that go into it. h. The Belt as above, which is to be tightly braced together by the Brace Bars. b. Which in Plate XXXI. is marked D. and you there ſee that they are to be about 1 Foot 8 Inches below the Heads of the Piles, and level to the top of the Piles is the Surface of the Platform of cut Stones, which are to be four by two Feet, and one Foot thick each; on which Platform or Floor, the Stone-cutter begins to ſet the firſt projecting Courſe of the Pier. i. In Plate XXXII. is the Middle of the Bridge; and k. the extent of the Parapets.

In driving down the Piles, you muſt begin with the Cut-water Pile, and obſerve, that in the fourth Joint that you are to run a cut of your Saw acroſs both the Tongues and Grooves, but not to take that upper Part off, 'till you are going to drop down your Belt; and you are to make the ſame Preparations for all the other Brace-bars; and when you are going to drop them down, rip off the upper Parts of the Tongues and Grooves to make Room for the Brace-bars.

I ought to have told you before, that theſe Belts muſt be made very ſlack, ſo that they may go eaſily on, and if they do not, and you are ſure there is nothing in the Way to obſtruct them, you muſt force them down with a ſingle Maul, 'till you come to the Surface of the Water; and if you chooſe to put any of them lower, you muſt drive them the reſt of the Way, after the ſame Manner as a Cooper drives down a Hoop.

The moſt of theſe Piles may be drove down into ſuch a Bottom, with a ſingle Maul, but you muſt alſo have ſome large and weighty double-handled Mauls, eſpecially for the corner Piles, and if the Bed proves ſuch as we have ſuppoſed, a Carpenter, a Boatman to keep your Float or Pont ſteady, and three ſtout Labourers, may

drive at the leaſt ſix of theſe little ſhort Piles in an Hour, and by having freſh Men to ſucceed them every eight Hours in Summer Time, you may quickly diſpatch the Coffer, provided, you have made proper Preparations for it as before directed, always obſerving to laſh all the Piles you drive in the Day very tight, leaſt an unexpected Rain ſhould come on, and for aught you know, bring down a Flood upon your Work; and in Caſe you have cauſe to ſuſpect a Flood, brace your Cut-water Pile with temporary Braces, in the ſame Manner of a. b and c. in Plate XXIII. and from thence diſperſe the Braces to the right and two obtuſe Angles of the ſtem of the Coffer.

SECT. II.

PROP. V. *IT is required to build the Piers for a Stone Bridge, in a ſmooth freſh Water River of ſixteen Feet deep, the Bed of the River Loam; the Proportions of the Bridge left to Diſcretion, as before.*

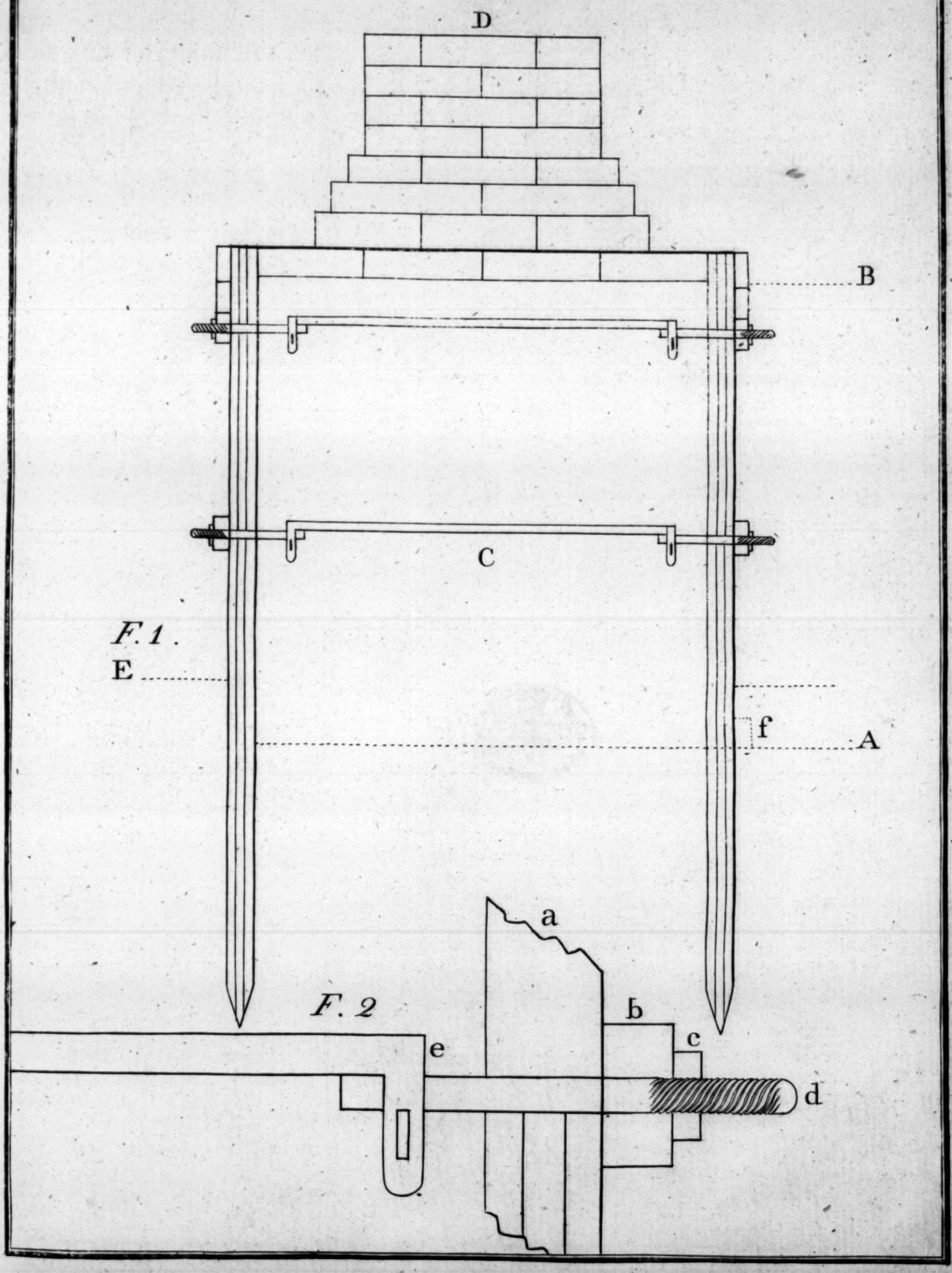
METHOD *laid down in* PLATES XXXIII, *and* XXXIV.
Scale 5 Feet 1 Inch.

PLATE XXXIII. Fig. 1. Section of the Coffer. Wherein note, A. The Bed of the River. B. Ordinary low Water in Summer. C. Section of the Coffer. D. Section of the Pier ſpringing high, ſtanding on the Platform or Floor of cut Stone. E. The Bank to be of the ſame ſort of Materials of the Stuffing, Lime only excepted.

Fig. 2. is laid down by a Scale of a Foot to an Inch. Wherein note, a. Is part of one of the Piles that compoſe the Coffer, having the Groove ripped off the upper Part of it, to receive the Brace-bar. b. Part of one of the Belts that ſurround it. c. The Nut that ſcrews it tight together. d. The Screw. e. The Brace-bar fallen down into its Place, and is to be keyed under the End of the Screw-bar, d. in which there is to be an oblong ſquare Hole, made to receive it.

PLATE

Pl. 33.

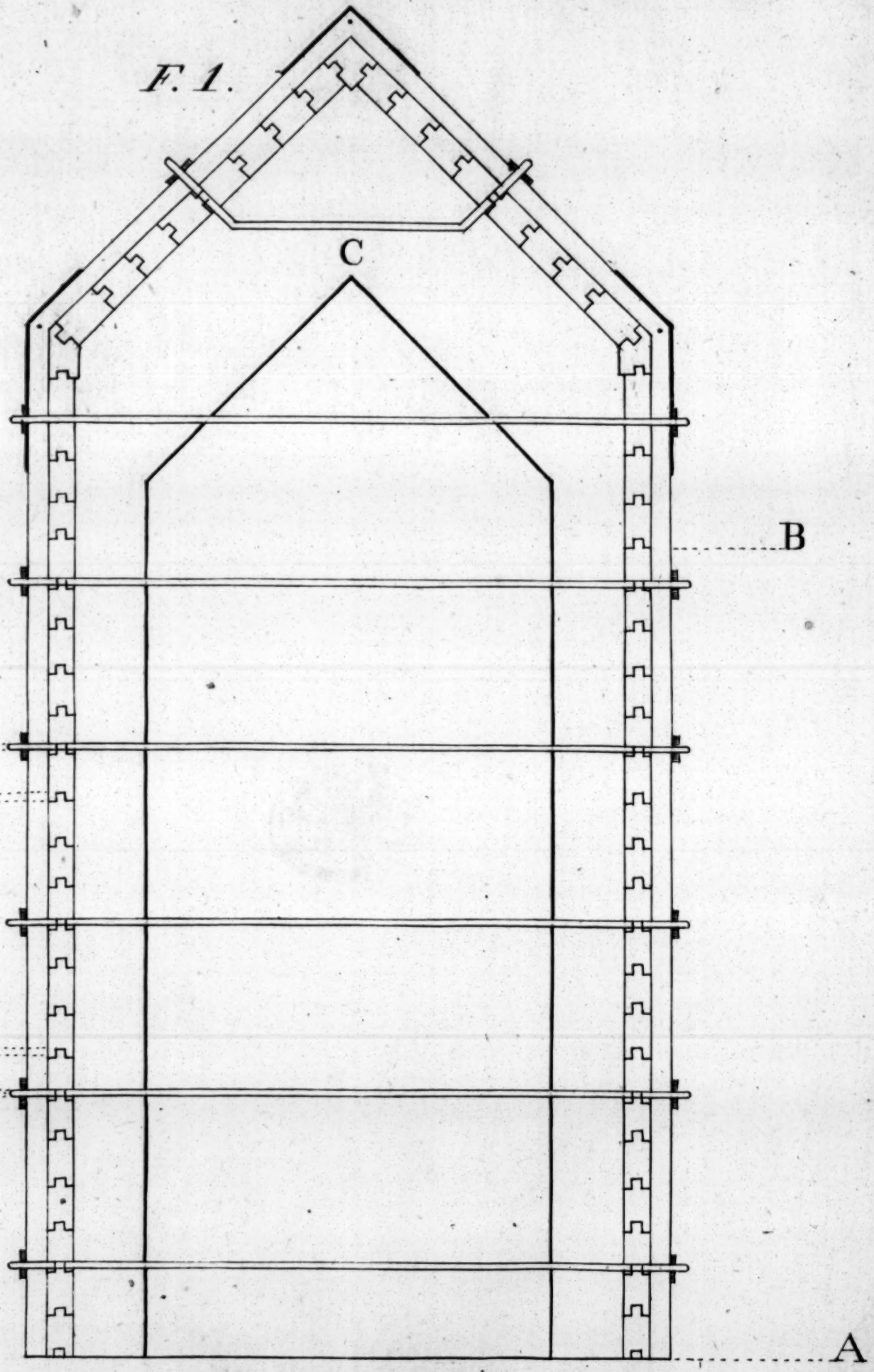


F. 1.

F. 2

Pl. 34.

F. 1.



F. 2.

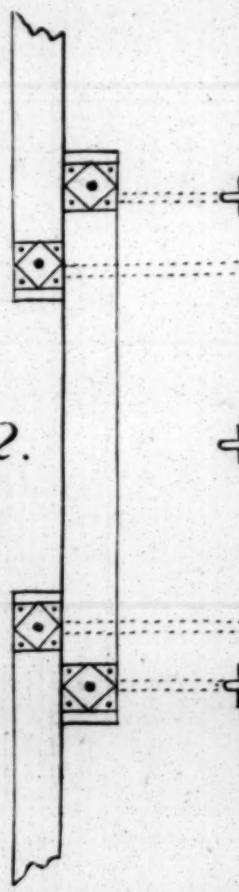


PLATE XXXIV. *Scale* 5 *Feet* 1 *Inch.* Is the Plan of the Coffer for one half of one of the Center Piers. Wherein note, A. Middle of the Bridge. B. Outſide of the Parapet, which from out to out is 47 Feet. The Center Arch is to be 48 Feet ſpan. C. Firſt Stone of the Cut-water in the firſt projecting Courſe of the Pier.

It may perhaps happen, that you may meet with ſome Difficulty, by fixing your Chain-braces ſo exactly, as to fall directly into the Joints appointed for them, and alſo, in ſplicing the long Sides of the Belts, ſo as they may not wreck in dropping them down; and if you apprehend that, then follow the Method laid down in Fig. 2. which ſhews how the Belts are to lap and break Joints, by which you will remove all the Difficulties, and make the Coffer extremely ſubſtantial, by dropping down your Brace-bars in pairs, as you ſee in this Figure drawn horizontally.

But I muſt give you a Caution, with regard to your ſtuffing this or the like Coffer. If you have a Bed of ſharp, clean ſandy Gravel, your firſt Stratum ought to be plenty of Roach-lime, in order to cement and petrify that Gravel, and then proceed with the reſt as formerly directed; but in Caſe your Bed ſhould happen to be fine, quick Sand, or ſoft ſpungy Ground, notwithſtanding your piling the inſide of your Coffer at 2, 3 or 4 Feet aſunder, yet, in ſome Caſes it may be very neceſſary, before you put in your Chains, to make a Belt pretty large, and drive it down (as I told you Coopers wrought) to the Bottom of the Water, as f. in Plate XXXIII. and that will keep all tight together below, and the banking, E. is to extend from Pier to Pier, and ten Feet above, and fifteen Feet below the Point of the Starlings of the Coffers, which will there make a firm new Bed for the River.

I recommend it to my young Reader, to bend his Attention to the Methods fully laid down in this and in the laſt Propoſitions, and principally exhibited in Plate XXXI. as I am convinced, that it may prove very uſeful not only for building in Water, but alſo in quaking Bogs or Moraſſes, that have ſmooth penetrable Bottoms, but eſpecially Loam or ſoft Clay. Remember then, when you are engaged in ſuch Works, in a ſtill or gentle running freſh Water, quaking Bog or Moraſs of a moderate Depth, that you may make

effectual

effectual Coffer-dams, by driving down ſuch Piles as theſe, anſwerable to the Intention and Size of your Work; only obſerving, that in forming the Angle, it will not be neceſſary to make uſe of ſuch groſs Scantling, as repreſented in Plate XXXII. Fig. 2. letter e. Becauſe Scantling of the ſame Size of d. d. will anſwer effectually, by pinning and ſpiking the Grooves on the corner Pile, and the Tongue on the next returning Pile, and all their Heads may riſe two or three Feet above the Surface, and there they may be cut off level, and a Ribbon run a long the outſide of them, from whence you are to dovetail ſtrait Beams or Braces of ſmall Scantling to keep all tight together, whilſt you have Occaſion for them; and when all that is done in a Workman-like Manner, then get the Water, Slough or Mud taken out, corking any Leakages that may happen to appear according as the Water ſinks; and when you have thus got the Coffer clear, ſtrengthen the Bottom by driving down ſquare Piles, or by laying a Grillage of Timber on it as before directed, and thereon let the Maſons go on with their Work after the uſual Manner; and when they have brought up their Work to a proper Height, theſe Piles that compoſed the Coffer are to be drawn out, and applied to another Pier or Part of the Work.

Single Rows of ſuch Piles, may alſo be extremely uſeful, in preventing or ſtopping ſubterraneous Leakages or Ouzings under Coffer-dams, Dikes, Sluices, Flood-gates, Wires, Canals, Mill-races or the like; and likewiſe an excellent Method to preſerve and to keep in the Ground that is under the Piers, either of a new or what remains under an old Bridge, provided they can be drove down, for theſe will take very little Room off the Water-way, and will be exceeding tight and cloſe tongued and grooved into one another, which is much better than any Thing that can be done by ſquare Piles. In ſhort, I cannot expreſs the great Advantages which I apprehend, may accrue or be deduced from this Method.

But in many Caſes it may be neceſſary to drive two Rows of theſe Piles, leaving a convenient Space between them, which is to be filled up with good and well rammed Clay, and that will unite with the Bottom, and make exceeding ſtaunch Coffers, or would

alſo,

alſo, effectually enable you to make ſtaunch dry Docks, particularly where ſeveral of them are ranged contiguous to one another, either in Tide-rivers, or within an incloſed Harbour in the Sea.

SECT. III.

Concerning the building of Stone Piers, in a deep Tide-river, on a hard rough Bed.

I HAVE already obſerved, and every Body may know, that there is a vaſt deal of Difference between the various Natures of the Beds of Rivers; and for that Reaſon we muſt invent ſuch Methods, as are capable of being varied in ſuch Manner, as may make them ſuitable to our Purpoſes; but as I aim at Conciſeneſs, I ſhall neither perplex you with a Multiplicity of Propoſitions, nor deprive you of ſufficient Room to exerciſe your own Ingenuity; and therefore, I ſhall State my next Propoſition, ſo as to comprehend ſome of the moſt extraordinary and difficult Circumſtances.

PROP. VI. *Let it be required to lay a ſure, quick and cheap Foundation for the Piers of a large Stone Bridge, in a ſpecious Tide-river, greatly expoſed to the Agitations of the main Ocean, the Bed of the River exceeding hard and rocky; in the Middle of which, there are ſix Fathom deep of low Water, whence the Bed riſes gradually on both Sides; the ſpring Tides ſometimes riſe four Fathom more; the Size and Proportions of the Bridge, left to Diſcretion.*

METHOD, *ſee* PLATES XXXV. XXXVI. XXXVII. XXXVIII. *In which I purſue the Methods pointed out by the firſt three Propoſitions.* PLATE XXXV. *Scale* 30 *Feet to* 1 *Inch.* Wherein note,

Fig. 1. Repreſents the Platform of the Coffers, for one of the Middle Piers in two ſeparate Parts, with the Plan of the Pier upon them.

Fig. 2.

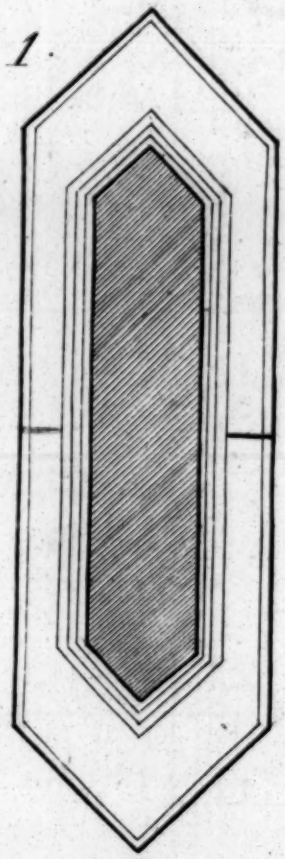
Fig. 2. Exhibits the Elevation of the Coffers, with the Pier ſpringing high. Wherein note, a. the natural Bed of the River, ſuppoſe then, at the Diſtances of b. b. you are to drop down Stones (none of them need be above a hundred Weight) in two direct Lines acroſs the River, by which you are to make two Stone Dikes or Banks, of 12 Feet high or more, theſe Stones are to be of all leſſer Sizes down to ſandy Gravel; and then you are to proceed and fill up the Pit, that theſe two Dikes or Banks will form to the level Line, c. c. with very ſmall Stones, Gravel and Sand, and as much Roach-lime as you can conveniently ſpare for it, always obſerving to throw the largeſt Part of it next the Stream of Ebb or Flood, and at other Times you may convey it by large wooden Troughs faſtened to the Sides of the Gabbards. This Line, c. c. is the Bed or Scite of the Coffers, and may be made higher or lower as other Circumſtances may require. And according as the Coffers are ſettled in their reſpective Places, or at any other Time when you find it moſt convenient, you may go on with banking or filling up the Pit after the ſame Manner, till you level it to the Lines, d. d. The low Water mark is e. And f. repreſents the Breadth of the Bridge from out to out of the Parapets, 54 Feet. And the Center Arch is to be 84 Feet ſpan, as you will ſee more particularly deliniated in the next Plate.

Plate XXXVI. by the ſame Scale, gives you the principal Lines of the three Middle Arches. Wherein note, that a. is the natural Bed of the River. b. The Bed on which the Coffers are to ſtand. c. The Bank or artificial Bed of the River, as before mentioned. d. Low-water, and e. High-water marks. f. The Pavement.

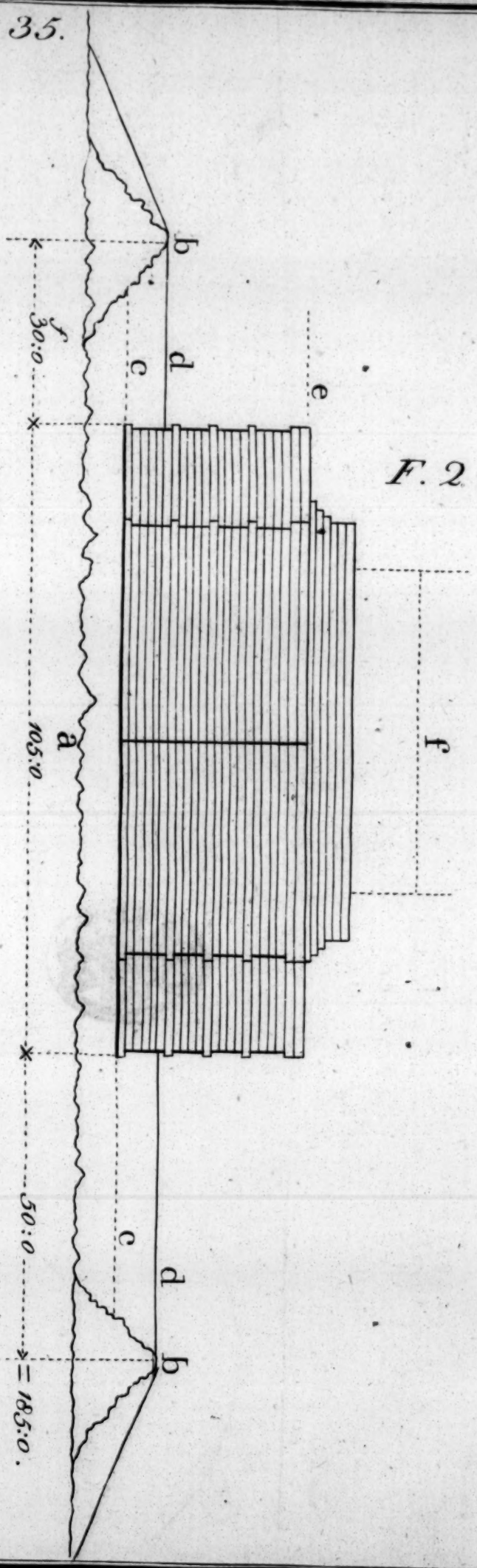
I do not doubt but ſome Readers may object, that thus raiſing the Bed of the River and theſe large Coffers, will dam and obſtruct the Current. In anſwer to this, you may be very well aſſured, that in all deep Rivers, the Current runs principally, and with the greateſt Velocity toward the Surface of the Water, and conſequently, thoſe can only increaſe the Celerity, but cannot obſtruct the Current; and in ſome Degree, this is alſo the Caſe in all Stone Bridges, and therefore, that Objection can have no Weight, becauſe, it is evident, that no diſadvantageous Concluſions can be drawn

Pl. 35.

F. 1.

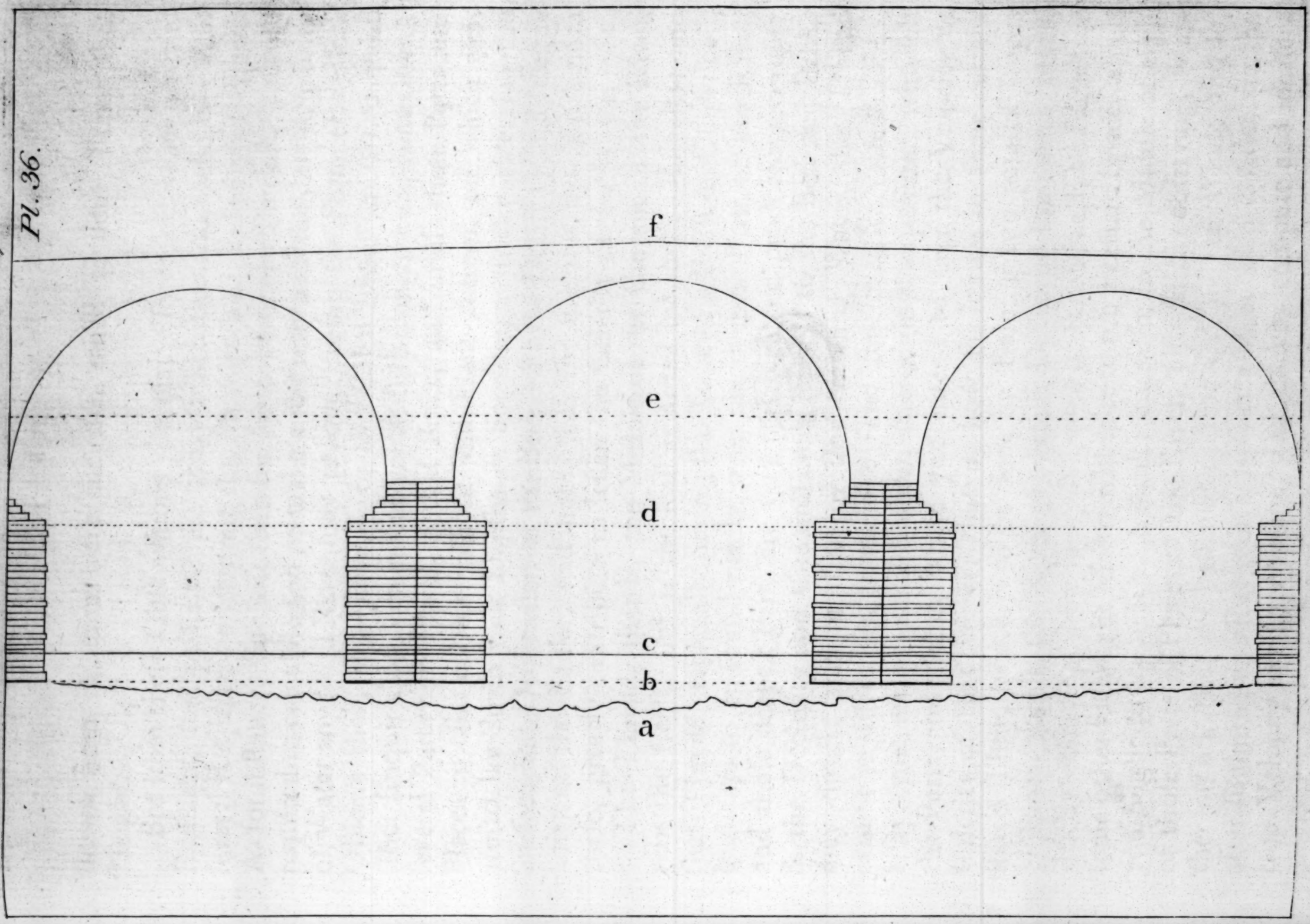


F. 2.





Pl. 36.



drawn from it, even were the Bed raiſed to four Times that Height.

But from theſe Obſervations you may alſo collect other material Remarks, that perhaps, may prove inſtructive and uſeful to you in ſeveral Reſpects, concerning the Motions and Velocity of Rivers. As for inſtance, Suppoſe that for ſome particular Purpoſe, you are required to calculate and to make a juſt return of the daily Quantity of Water any ſmall River may produce during the Summer Seaſon: Obſerve then, that previous to that Calculation, you are to make ſtrict Enquiry, and to make yourſelf thoroughly acquainted with ſeveral Parts and Places in that River, and in all thoſe Parts and Places to take correct Sections and Plans thereof, on which you are to lay down your Depths or Soundings, ſtrictly obſerving the Surface and Declination of the Bed, and the Declivity and Irregularity of the Banks; and note, that the Friction that ariſes from theſe, greatly contribute to leſſen the Celerity of the Water.

The Thread, that is, the Middle of the Current of the River, runs the freeſt, and is the leaſt retarded by thoſe Obſtacles; and that Thread, eſpecially during the Time of a Freſh or Land-flood, is always to be found nearly over the deepeſt Parts of the River, and thoſe deepeſt Parts are very variable, and produced according as the Declivity and Circumſtances relative to the Bed and Banks may direct; and in dead or ſlow running Water, this Thread cannot be diſcovered by the Eye; and therefore, for theſe Reaſons, I ſay, you are to make yourſelf thoroughly acquainted with all the Parts and Places, where you intend to take the Velocity or Celerity of that Water; that is, how far it runs in ſome certain ſtated Time, which is to be done by ſtraining two parallel Ropes or Lines, acroſs the River at certain Diſtances from each other, ſtrictly obſerving, how many Minutes or Seconds a Bit of Cork or ſome other ſuch light Matter will take to run a certain Space, which you ought to try near each Bank; and alſo, in the Middle of each of thoſe Parts or Places of the River, alſo ſtrictly obſerving, whether or no, they are haſtened or retarded by the Wind; and ſo, after ſumming up all together, you may be enabled to calculate the true Velocity on an Average, and thereby compute and meaſure

the cubical Feet of Water, that you may reaſonably conclude to paſs through and may be produced by it in the Time required, making rather large Allowance for waſte, *&c.*

There have been numerous Perſons involved in very ſerious and diſagreeable Circumſtances, both of private and public Natures, on the Credit of ſuch Calculations as theſe; eſpecially, where they have much exceeded the Truth, and thereby deſtroyed and rendered hopeful Schemes abortive, that might perhaps, otherwiſe have been attended with private and public Utility.

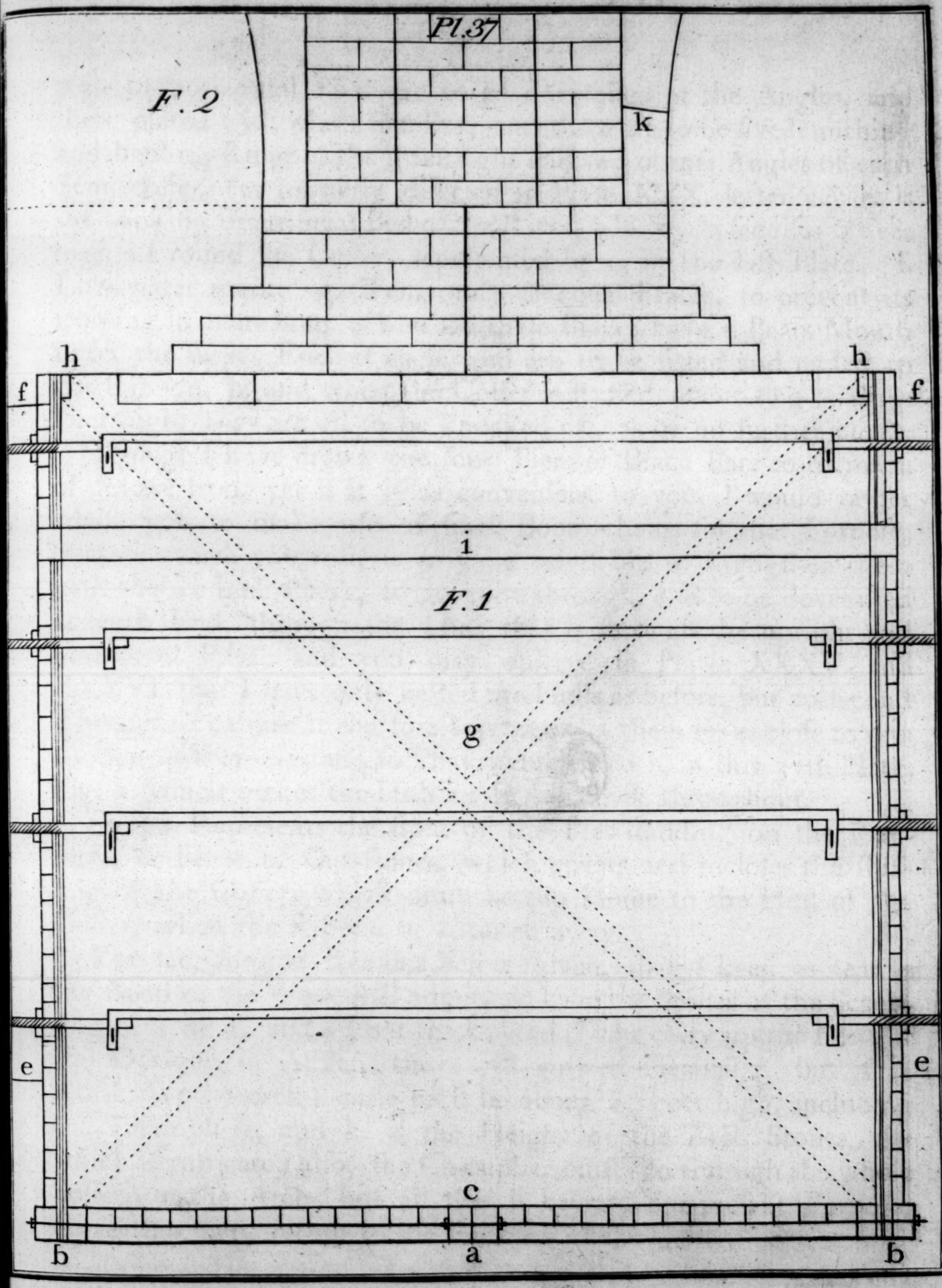
Hence alſo, you may conceive ſome uſeful Ideas, concerning the Motions and Velocity of Rivers in general, but diſtinguiſh and remember, that rapid Land-floods roll down and principally acts from the Surface to the Bottom in all deep Rivers, as I hinted above, and that when a Flood Tide flows into the Mouth of a River over a ſhallow Bar, it operates from the Bottom to the Surface, by damming up, and totally overpowering all the freſh Water that comes within its Influence. But to return.

Now, I hope, I have furniſhed you with general Ideas of the Nature of the Works, which you are going about; let us in the next Place, conſider the Conſtruction of theſe Coffers. See

PLATE XXXVII. *Scale* 5 *Feet to* 1 *Inch.* Fig. 1. Repreſents the Section of the Coffer; but obſerve as before mentioned, that this Coffer would be too large to be made in one, and therefore, I propoſe, that it be made in two ſeparate Parts. Whereon note, that a. is the Bottom. b. b. The double Sills between each pair of them; the upright Planks that compoſe it are to be placed erect, and are to be the Tenons of the Hull, and then they are to be pinned and bolted together. c. is the Keel or Middle Sill, and as probably you cannot get Timber long enough for them, you muſt run a breaking cut through the longeſt you can get, ſcarf them to fit your Length, and turn them End for End, and bolt them firmly together with Nuts and Screws; between theſe, you are to grate the Bottom with two Courſes of ſix Inch Plank, croſſing one another. Both the upright and horizontal Piles of the Hull are to be tongued and grooved as in Plate XXXI. Fig. 2 and 3, and all of them to be pinned together at their Interſections, and all the outward

Pl.37

F. 2



ward or horizontal Piles are to be dovetailed at the Angles, and there plated with whole flat Bar; and there are to be five launching and hauling Rings at the three right and two obtuſe Angles of each Semi-coffer, (as formerly directed in Plate XXX. letter a.) e. is the banking or artificial Bed of the River, which you ſee riſes 6 Feet high all round the Coffer, repreſented by c. in the laſt Plate. f. Low-water mark. g. Temporary diagonal Braces, to prevent its warping in launching. You ſee theſe Braces have a Bears Mouth upon the upper End of each, and are to be fitted and nailed to the Ribbon, h. and when the Coffer is ſtuffed about two or three Feet high, they are all to be knocked off, as of no further uſe.

Though I have drawn the four Tiers of Brace Bars to be made of ſquare Iron, yet if it is as convenient to you, I would rather adviſe you to make uſe of ſmall Boom-chains for that Purpoſe; but uſe which you will, it may be adviſable to ſtrengthen them with the ſix Inch Plank, to go quite through, and to be dovetailed at each End, through the Hull that is through the upright and horizontal Piles; and you may obſerve in Plates XXXV. and XXXVI. that I have only belted the Hulls as before, but on ſecond Thoughts, I think it the ſureſt Way to let them lie as cloſe to one another as they can, and ſo I have repreſented it in this 37th Plate, Fig. 1. which makes the Hull 12 Inches thick throughout.

Fig. 2. Repreſents the front of the Pier ſtanding on the Platform, or Floor of Cut-ſtones, which covers and incloſes the ſtuffing of the Coffer, which muſt be run Home to the Hull of the Coffer, when the Ribbon h. is taken away.

You ſee, for the Reaſons before given, that I keep as near as the Bond of the Work will admit, to have the Stones of the Scantling of 4 by 2, and a Foot thick; and if you carry up the front of the Octagon in Aſhler, they will anſwer effectually, but if in Ruſtic Work, each Courſe muſt be about 2 $\frac{1}{2}$ Feet high, including the Champhers, and k. is the Height of the Arch Stones, the which if ruſticated alſo, the Champher muſt run through the whole Soffeto of the Arch; but all this is beyond our preſent Purpoſe; let us therefore, return to the finiſhing of the Coffer. See

Plate XXXVIII. *Scale* 5 *Feet to* 1 *Inch.* Fig. 1. Repreſents the reſpective horizontal Situations of the Chains, and the reſt of this Figure ſhews you the Surface of the Cut-ſtone Floor, that is to finiſh the Coffer within the Hull. Fig. 2. Shews you the Scite of the three projecting Courſes of the Pier, and the third Courſe of the Body of the Pier, and the Bond of the Work in that Courſe. In theſe ſix Courſes, that together carry you to the ſpringing, there may be three of the Courſes chained with two Inch ſquare Bar, ſunk quite down into their reſpective Courſes, and run with melted Lead as uſual.

I have already adviſed that all the Cut-ſtone Floor, or Platform, is to be carefully and cloſely ſet in ſwimming Beds of choice good Mortar, and all the Joints with Tarraſs Mortar, and if you do not think that ſufficient to withſtand the Effects of the Water, you may at any Time afterwards ſcrape the Joints clear for about two Inches deep, and either fill them with melted Lead, or rather cork them with the ſhavings of Lead, but only for ſo far, as exceeds that firſt projecting Courſe. The ſeven ſtrong Lines, d. repreſent the Cramps, that are to cramp the Hull and the cut Stone Floor together, which you will hereafter find more fully deſcribed; only obſerve, that they are to be lodged in the ſecond Courſe of the Stone.

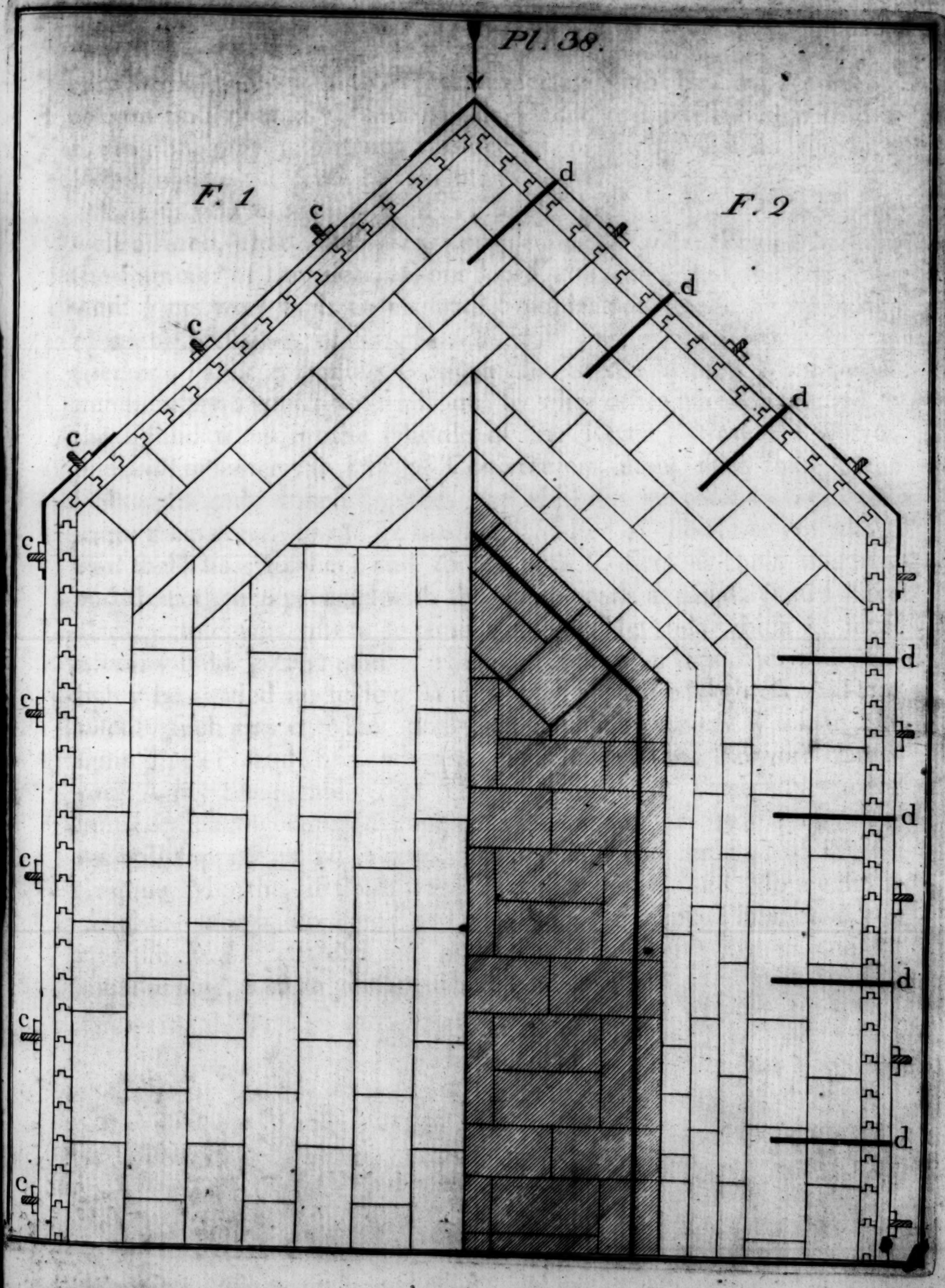
And now I have furniſhed you with an Idea of my Intentions, pray point out any one individual particular in this Method, that is attended with the leaſt Degree or appearance of Impoſſibility, or even of any extraordinary Difficulty. Surely, you will not pretend to ſay, there is any Difficulty in making the two Half-Coffers, which may be put together by a very few Journeymen Ship and Houſe Carpenters, and a few Black-ſmiths, with the Aſſiſtance of a few Sailors and Labourers, in a Fortnight's Time; and if you are required to uſe any extraordinary Expedition, you may eaſily have them launched and ſtuffed within another Fortnight, provided you take proper Care to have every Thing you will want timely and conveniently provided, and that you have proper Crafts to carry in your ſtuffing, which by the Aſſiſtance and Direction of your ten-buoy Ropes belonging to your two Semi-coffers, the Men

may

Pl. 38.

F. 1

F. 2



may work at low or high Water, either by Night or Day, according as you find neceſſary; and if this Coffer can be ſtuffed within a Fortnight, pray might not another ſet of ſuch Men do the like Work within the ſame Fortnight?

Let us now compare ſmall Things to great ones. We are very well aſſured, that *Apollodorus* compleated *Trajan*'s Bridge within the Summer of the Year of our Lord 104, and that the ten outward Piers were built on artificial Foundations, made by wheeling in vaſt Quantities of large and ſmall Stones, and other filling (perhaps like the ſtuffing ſo much uſed by the Antients) but by all my Induſtry I could not find out, by what other Methods he made the Foundations in the Middle of the River. Now if I was to preſume to enter the Liſt of Conjecturers, along with ſome great Folks, I ſhould conclude, that the Methods he took to build the inner Piers were, to riſe or bank up the Bed of the River (of which you ſhall hear further) and to ſet ſuch Coffers as theſe thereon, and from thence proceed with the Stone-work as uſual; (and I have already told you where to find the true Methods which he muſt actually have taken) and if the Foundation of one Pier can probably be carried up to low Water mark in a Fortnight, could not twenty ſuch ſets of Men, do twenty ſuch Pieces of Work in the ſame Time? And if ſo, where is the Wonder that *Trajan*'s numerous Army compleated that Work within that Time? Nor need you be afraid to compleat ſuch an one as we are now projecting, we will ſuppoſe of 19 Arches, even within the compaſs of the ſix Summer Months, if there was a Neceſſity for it, and Money ſufficient to carry it on, provided you had ſufficient Time, and you had previouſly provided and prepared every Thing you wanted for the Purpoſe, before you launched your Coffers.

SECT.

SECT. IV.

Concerning Bridges principally contrived for the Uſe of LONDONDERRY, WATERFORD, *and* WEXFORD, *and for ſuch other large and deep Rivers.*

THROUGH the Courſe of my Endeavours to contrive and find out effectual Methods for building Bridges and other Works in deep Waters, *Londonderry*, *Waterford* and *Wexford*, (each of which I have viewed) have conſtantly enjoyed a prime Place in my Mind; and being thoroughly acquainted with many intolerable Diſadvantages, that not only the Inhabitants in, and the Proprietors of thoſe and the adjacent Places, but the Public in general daily ſuſtain, through their want of Bridges; theſe Conſiderations alone, have excited my moſt zealous Endeavours to find out proper Methods to redreſs thoſe Grievances, and not in thoſe Places only, but in many others in like Manner; and with that Intent, I here freely tranſmit and communicate to you my Sentiments and Ideas on this important Subject. And I am ſure that they are conſidered, and well weighed to the utmoſt extent of my Capacity, and that they are not only practicable, but by a prudent Application of what I am now laying before you, may be productive of immediate Utility, and anſwer according to the Appellation beſtowed on them, of being ſure, quick and cheap Methods, for thoſe and the like ſalutary Purpoſes.

The Conciſeneſs of this Work, and not being able to procure proper Sections of thoſe Rivers, prevented my laying them down particularly, nor have I formed any Deſign exceeding ſix Fathom low Water; but I hope they moſt clearly point out, Methods for building in a much greater Depth. As for inſtance, let us ſuppoſe a River of fifty Feet deep at dead low Water, and let us examine, after what Manner our general Rules muſt conduct you to draw Deſigns for that Depth. The principal of which directs, " that " the Coffers ſhould at the leaſt extend to a Cube of the Water

" they

" they ſtand in; and that the Size of the Bridge ought to bear " ſome Proportion to the Depth of the Water in which it is to " ſtand." Now if the Water be 50 Feet deep, the Coffer muſt at leaſt be 50 Feet broad, the naked Body of the Pier 25 Feet, and conſequently the Arch muſt Span 150 Feet. I grant that ſuch a Span would not by any Means anſwer for our poor Country, becauſe the Expence would riſe infinitely above any Thing that we could have the leaſt Hopes of accompliſhing. Now to remedy this, the Method is obvious, turn back to Plate XXXVI. and obſerve the Line b. which is the Scite of the Coffers and diſtant from a. but ſix Feet, which is placed in the Middle of the River. Now, we muſt ſuppoſe a. to be 20 Feet beneath b. and let a. be ſuppoſed to lie as far as you pleaſe either to the right Hand or to the left, and let a. and b. be either more or leſs than 20 Feet; the Method is, to raiſe up and make an artificial Bed of the River, with ſuch ſmall Stones and Gravel as formerly directed, till you bring it to the Line b. and to extend it in Breadth on the Bottom in Proportion to its Height; and then every Thing elſe will fall in, in due order. Hence it is evident, that let the Depth of the Water be what it will in Moderation, the Rules may help to conduct you in drawing Deſigns for any other reaſonable Depth.

But perhaps, after all I have ſaid, you may object, that this banking or artificial Foundation would not be ſufficiently ſtrong for the Purpoſe.

You have been repeatedly informed, that in building *Trajan*'s Bridge, *Apollodorus* had " the ten outward Piers built on an " artificial Foundation, by wheeling in vaſt Quantities of large " and ſmall Stones, and other filling, after the uſual Manner of " carrying a Mole into the Sea."---Let us here obſerve, that our Hiſtorian ſays, " after the uſual Manner of carrying a Mole into " the Sea." And that notwithſtanding thoſe Rivers are greatly agitated at ſome Times by the Sea, yet not liable to be quite ſo much ſo, as " a Mole projected into the Sea," whoſe Surface is expoſed to the Waves of the Ocean. Therefore, it is evident, that if this Method was ſufficient for ſuch an enormous Bridge, ſurely there cannot remain the leaſt Objection againſt the Stability of ours.

But

But pray give me leave to engage your Attention in a more particular Manner. It muſt be admitted, that this Country cannot afford to carry on any expenſive or very ſumptuous Work for want of Money; but if we have a Scarcity of Money among us, I am confident, that we have ſuch very great plenty of ſmall Stones and Gravel, that in every navigable River in this Kingdom, you may be abundantly ſupplied with theſe common and in a Manner inſignificant materials, and together with the Labour of a few Gabbard-men and Labourers, ſuch an artificial Foundation may be accompliſhed at a very ſmall Expence; and that either of thoſe three Corporations, with the aid of ſome of the principal Proprietors adjacent, even in Caſe they got no help from the Public, need not in the leaſt be afraid of compleating ſuch a Work. And as theſe common Materials can be ſo eaſily procured, it will conſequently follow, and the leaſt Degree of Prudence will direct you to raiſe the Bed of the River as high as you think convenient with theſe cheap Materials, in order to ſave Labour and other Materials that would prove infinitely more expenſive. And thus reducing the Depth of the low Water, perhaps to eight Feet, allowing four Feet of that for the Banking, and four for the Navigation; you are thereon to build the Bridge, according to the Plans and Methods hitherto and hereafter exhibited, or according to any other Proportions, that you may think moſt agreeable to their reſpective Situations, paying due regard to the Heights of the Banks, Quays, *&c.* and particularly obſerving, that the higher you raiſe the Bed, the leſs Money you will require to build the Bridge; but I ſay you muſt pay due regard to the Navigation of the River above the Bridge, for if you leave low Water deep enough for that Purpoſe, you need not ſcruple in ſome Rivers, to raiſe the Bed ſo, as to reduce that Part of River to a perfect Ford, which all People ſearch for that are concerned in the like Work, and which, you may make perfectly ſubſtantial, if you adhere to our former Concluſions. Therefore, if Nature has not provided a Ford agreeable to your Purpoſes, you may have it in your own Power to ſupply that by Art, which you find you cannot enjoy by Nature. Hence you may alſo deduce an excellent Method of making or rendering a dangerous Ford, much

more

more ſafe for Travellers, even for Carriages of any kind, and the Expence will be but a Trifle to a County, where they might not be able to build a Bridge.

Theſe brief Conſiderations, I thought previouſly neceſſary to prepare you to form a clear Conception of the particular Methods which I have contrived for, and I adviſe you to lay them before the Gentlemen of your Committee, but that ſhall be the Buſineſs of the next Section.

SECT. V.

On an exceeding cheap, and moſt ſubſtantial Method of building a Bridge, in a very deep and ſpacious River, which may be grafted on any of the former Methods.

HAVING fully proved and demonſtrated on the ſix Propoſitions, ſo far as the Nature of my preſent Deſign requires, that theſe are eligible Methods to build Stone-bridges in deep Rivers; it is incumbent on you to make yourſelf thoroughly acquainted with theſe Matters, and to apply your Attention and the utmoſt extent of your own Genius, to conſider and improve them according as you find it neceſſary: And after all, you may probably find yourſelf far ſhort of Arguments ſufficient to ſatisfy every Member of your Committee, which are generally compoſed of Gentlemen of various Abilities; ſome of whom, may perhaps, readily conceive and approve of what you offer, but others, may differ widely from them. In this Caſe, I adviſe you to enquire among your Acquaintances, and take Notice yourſelf, which of the Gentlemen ſeem to be beſt acquainted with the ſurpriſing Performances of the Antients, in Works of this or the like Nature; for ſome of theſe will be the moſt likely to ſupport your Arguments, and this may incline the Majority in your favour. But ſuppoſe you fail herein, I have ſtill a powerful Argument which cannot fail of meeting with the Attention of the Board, *viz.* that you ſhould proceed with your Coffers, by either of the Methods

pointed out in the laſt Section, which will bring your Foundations, that is the Lip of the Hull, one Foot above the low Water mark, as repreſented by d. in Plate XXXVI. and thereon erect Piers either of hewn or rough Stone, or both juſt as they agree, which would ſufficiently anſwer your Purpoſe, and which you may begin upon the Platform, Plate XXXVIII. Fig. 1. But it would do beſt to begin them on the ſpringing Courſe, repreſented in Fig. 2. and alſo in Plate XXXVII. Fig. 2. and thereby to make a ſubſtantial temporary Bridge with Timber, at ſuch a trifling Expence as would not be worth Notice, in Compariſon to what it would coſt, if done in any other Method that I have ever heard of.

This Thought when firſt ſuggeſted, actuated by the Motives before mentioned, actually carried me beyond the Limits of my former Intentions, which related to laying Foundations in Water only. However, I indulged it ſo far, as to endeavour to furniſh you with a Deſign of ſuch a temporary Bridge, as may perhaps, fully anſwer the moſt ſanguine Expectations of your Board and the Public; and which I ſhall deſcribe and demonſtrate, on the following Propoſition.

PROP. VII. *You are required to lay down ſure, quick and cheap Methods, for the building of a moſt ſubſtantial temporary Bridge, with Stone Piers; the Arches (or the Spaces between the Piers) are to be made of Timber; the River at ſome ſpring Tides is ten Fathom deep, as was more fully deſcribed in the laſt Propoſition.*

METHOD *laid down in* PLATE XXXIX. *Scale* 12 *Feet to* 1 *Inch.*

Let us here ſuppoſe, that the Coffers are ſtuffed and floored over with cut Stone, as repreſented in Plate XXXVIII. Fig. 1. on which you are to be determined, whether you are to go on with the cut Stone Work to the ſpringing Courſe, as Fig. 2. and alſo Fig. 2. in Plate XXXVII. or whether you are to begin the temporary Pier on the Floor or Platform of cut Stone; but I ſhould adviſe you to the former, becauſe it will be better, and there will be ſo much done for the next Generation; but in either of theſe Caſes, obſerve, that

Plate

Pl. 39.

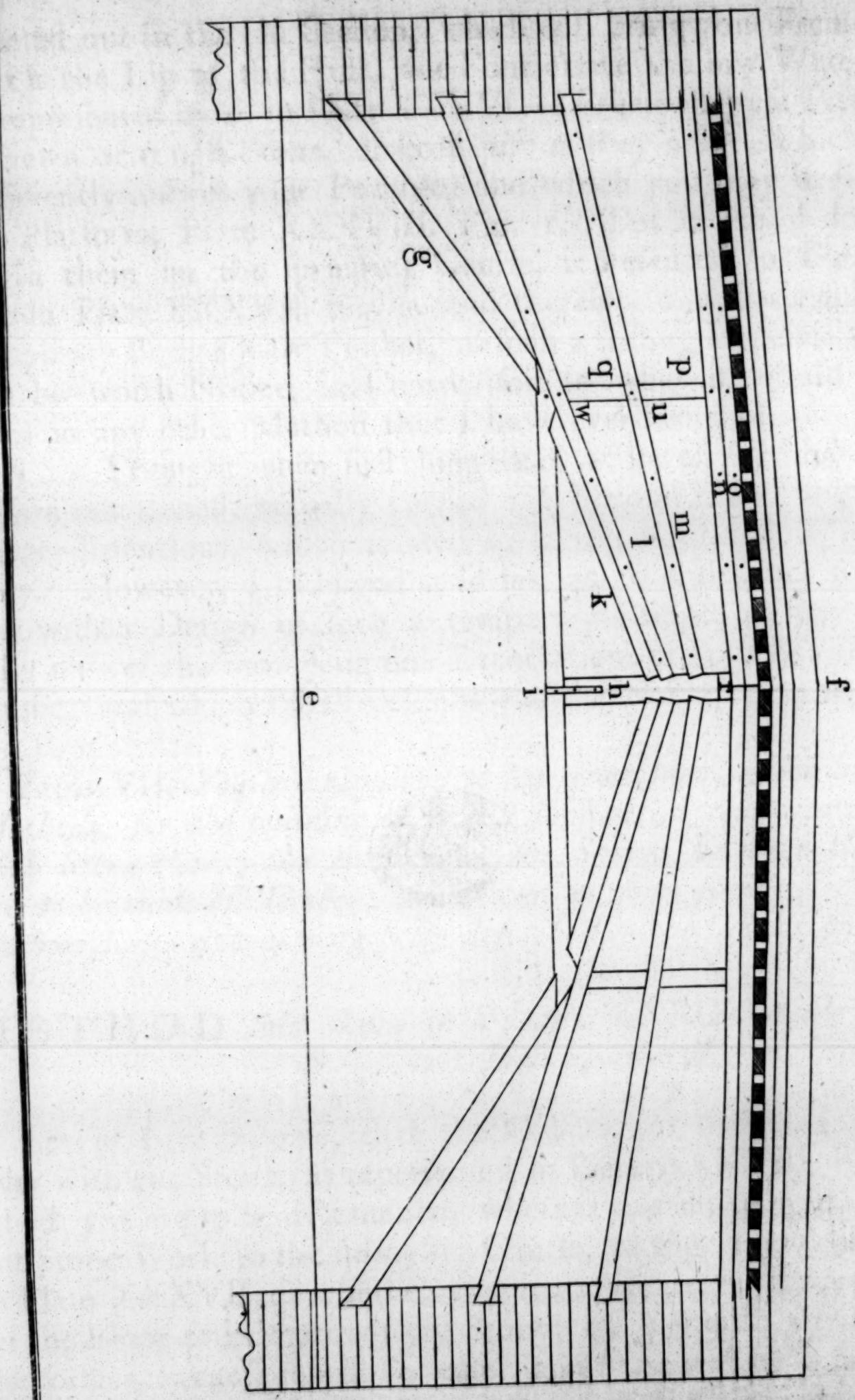


Plate XXXIX. is deſigned from the high Water mark of the laſt Propoſition, and extends to half of the two middle Piers. Wherein note, e. Is the high Water mark, which is the ſame of e. in Plate XXXVI. and in both. f. Is the Surface of the Pavement. g. The lower, or principal Braces, which ought to be made of ſound hearty upright Oak, of 18 by 12 Inch Scantling. And the King-poſt, h. may be the ſame; but all the reſt of hearty and ſound red Fir. i. The Collar-beam. k. Principal, l. and m. The two main Braces. n. and o. The principal Beams, which you ſee lie one upon the other (but it would be adviſeable to lay Slips of ſound Oak Plank between them, upon a ſlant, to turn off the Rain Water, and particularly the out-ſide ones, to keep them from rotting) Theſe four, *viz.* l. m. n, and o. Are to have breaking Cuts run through them, and turned End for End, and then bolted together, provided that your Span is as great as this. The Prick-poſts p. and q. are deſigned to ſhorten the bearing, and unite their Strength. All theſe, that is, i, k, l, m, n, o, p, q, are to be about a Foot ſquare; and each of the Frames are to be placed about four Feet diſtant from each other, the outward ones are to be tried up, *&c.* The crown Beam r. is 18 by 12 Inches. The flooring Joiſts which lie on the Beam, o, are to be nine Inch Scantling, and ſpaced at 18 Inches aſunder. On theſe Joiſts the flooring Planks are to lie, which are to be ſix Inches thick, this Floor may be firſt covered with Pitch and Tar, and then with common Slates, and one or two Courſes of Bricks on them, laid in ſwimming Beds of choice Mortar, cloſely wrought and grouted. Theſe Slates are to preſerve and prevent the Mortar from corroding the Planks, and over the Bricks lies the Pavement of the Carriage-way, f. for which ſee Plate XIX. Fig. 3. and the Foot-ways may be the ſame as therein alſo delineated. Theſe Slates, Bricks and Stones, if properly executed, will effectually throw off the wet, and help to preſerve the Timber; but do not forget that I have mentioned different Methods for that Purpoſe, but they are to be applied at your own Diſcretion. And I think it would alſo be very adviſable, to have this Bridge incloſed with a Stone Balluſtrade, at leaſt over all the Arches; but in this Caſe, there muſt be a pair of Frames placed together at the Extre-

mities, to ſupport the Parapets, which muſt reſt on a heading Courſe of cut Stone, of about 4 Feet long each, and Chain-barred, &c. for if it is incloſed with Timber, it will be a perpetual Expence to keep it in order.

I need not be at the Trouble of enlarging on the Strength of theſe Timbers, as I preſume, it is obvious enough, that they are ſufficiently ſtrong, to ſuſtain the Weight of any Carriage whatſoever, perhaps, for a hundred Years without any Expence worth mentioning; but you are to obſerve, that the Pavement muſt have reaſonable Time to cement, and that it is to be plentifully covered with Gravel, before any weighty Carriages are allowed to draw over it. As to the Expence of the Timber neceſſary herein, that I have not eſtimated, but I can venture to ſay, that I believe all this Timber and Workmanſhip, would not very much exceed the Expence of the Centers, Sheeting, &c. that would be neceſſary to turn ſuch a Stone Arch upon. As to its Durableneſs, if there be proper Care taken to prepare and preſerve the Timbers of the outſide Frames in particular, which are to be expoſed to the Weather, but eſpecially at the Joints, u. w. and to throw the Water off from rotting the Buts of them that go into the Wall, I am confident that the reſt of it, which has the benefit of the open air, and ſo effectually ſheltered, muſt in the whole laſt at leaſt as long, as Fir Timber can be expected to laſt in any other building.

Thus, you now ſee before you, the Method which I have ſo particularly recommended to the Conſideration of the Gentlemen of thoſe three Corporations, or of any other Community, that are in the like Situations; and all that I think now remains, is briefly to move one Conſideration more with reſpect to Roads, which are neceſſarily connected with our Subject.

I have already obſerved, and the leaſt Degree of common Senſe will direct, all Perſons concerned in projecting a Bridge in any Country Place, to look out for a Ford or ſome ſhallow Part of the River, becauſe, it will probably, be both cheaper and the more expeditious. And that by purſuing theſe Methods, it is evident, you need not be under the leaſt Anxiety with reſpect to the Depth of the Water, provided it be in Moderation. Therefore,

fore, before you fix on the Scite of the Bridge, (if that be left to you to determine) you are to procure correct Maps of the adjacent Country on both Sides of the River, view the Grounds yourself, and conſider not only the Roads that are made, but alſo ſuch Roads as muſt be made hereafter; and then ſumming all up together in your own Mind, you are juſtly and impartially to recommend the beſt Scite for the Bridge, that you are convinced will be moſt for the Advantage of the Public in general, without paying the leaſt regard to any one particular Proprietor of the adjacent Lands, nor ſuffer yourſelf to be knowingly led into an Error, that may either injure your Character, or prove prejudicial to the Public, without fairly and fully extricating yourſelf from any Charge that may afterwards be brought againſt you, let the after Conſequence be what it will.

If you ſhould happen to be in any Ways concerned in Military or Naval Affairs, then theſe Methods may alſo in other Reſpects become of ſtill greater Advantage, but eſpecially in remote or deſolate Countries.

His preſent Majeſty has of late Years made great Acquiſitions, and extended his Arms almoſt over the whole Globe. It is evident that theſe Methods may probably be attended by very ſalutary Conſequences, to the Inhabitants of thoſe Countries in general, where large Stone Bridges could not be accompliſhed in deep Rivers, for want of a ſufficient Number of Workmen, and proper Materials for it. But further,

If a new Bridge happens to be built in any Country Place, the Public ought to be conducted to it, and that cannot be done without making new Roads; in the Execution thereof, various Difficulties may happen to be met with. There is no Doubt but it will be deſigned, that this new Road will be carried in direct Lines; perhaps, Part of a freſh Water Lake may Intervene; and frequently freſh Water Lakes, quaking Bogs, Moraſſes or the like, happen in the Way and obſtruct laudable Deſigns, obliging the Undertakers to carry the Roads many Miles about, to the no ſmall Diſadvantage of the Public. Now let us endeavour to ſurmount theſe Obſtructions, and conſider what eligible Methods may be purſued,

in

in order to carry a Road in a right Line through ſuch Places, not only to accommodate the Public, but as being productive of various other Advantages to private Property, in draining and reclaiming flooded or boggy Grounds, by interſecting the Current, and giving it a more advantageous Direction.

CHAP. XVI.

Concerning ſome Endeavours to apply Coffer-work to other private and public Purpoſes, on Land or in Freſh Water.

IT is not my Intention, neither is it poſſible for me to point out all the various Purpoſes, to which Coffer Work may be applied; but I ſhall now give an Inſtance, wherein I think both private and public Utility are greatly concerned, in order to excite your own Ingenuity to extend it.

Our Country greatly abounds with deep moſſy and marſhy Grounds, numerous Loughs and freſh Water Lakes, to the great Loſs and Detriment of the Proprietors and Public in general: Let us, therefore, try whether or no any of theſe Methods may prove uſeful either for the reclaiming of Ground, or ſhortening the Roads in populous Countries. As for inſtance.

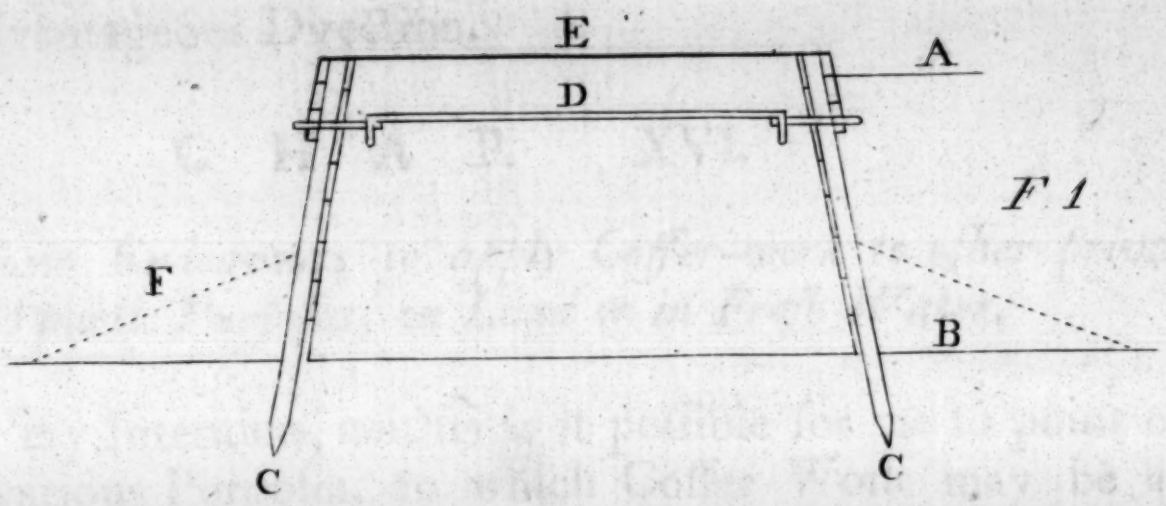
SECT. I.

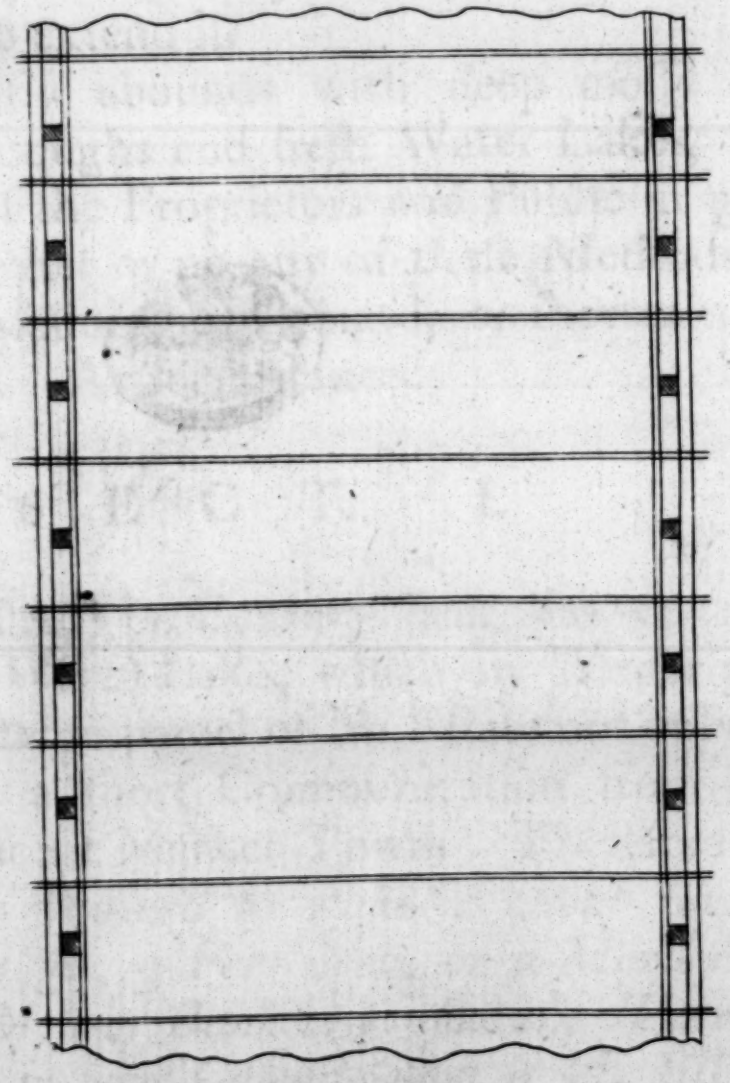
A GENTLEMAN's Country Seat lies contiguous to a ſpacious freſh Water Lake, which in Winter greatly overflows, and renders a large parcel of his Eſtate not only uſeleſs, but alſo entirely obſtructs a ſhort Communication from that Neighbourhood, to an adjacent Market Town. Therefore

PROP. VIII. *It is required to make a cheap temporary Road through part of a Lough, 9 Feet deep, on a Marley Bottom, that may alſo ſerve as a Mole or Bank to confine the Water from overflowing the Land; or in ſome Caſes to dam it off, till a ſubſtantial Imbankation may be erected.*

METHOD

Pl. 40.





F. 2.

METHOD *laid down in* PLATE XL. *Scale* 8 *Feet to* 1 *Inch.*

Fig. 1. Repreſents the Section of the Mole, wherein note, A. is the Surface of the Winter Water, which is 9 Feet deep to B. The bottom of the Water. C. C. Two Rows of ſquare Piles, to be ſheeted on the inſide with 1 ½ Inch Plank, which muſt be ledged together, and floated in on Edge between the Piles and temporary Poles, to keep the Sheeting upright in its Place till the Stuffing is put in, and then the Poles are to be taken away. D. The Chain that Braces both Sides together, which need not be very ſtrong as theſe Piles are battered. E. The Road or Surface of the Mole, and F. The Bank of any common filling.

Fig. 2. Is part of the Plan of the Mole with the Sheeting on the inſide, and the double Ribbons on the outſide of the Piles (like Fig. 2. Plate XXXIV.) with the Chains that are to ſtrain them in, and keep them to their batter, which may either be very ſtrong Plow Chains, or Inch ſquare Bar Iron, *&c.*

You are to begin your Stuffing and Banking at the Shore, whence you are to be ſupplied with it, and to carry them both on together, and your Carts and Cars having ſufficient Room, they are all to come in on the right Hand, and return to the left, to keep them from interfering; and whilſt this is doing, your Carpenter is going on with another range on each Hand before them.

If this lies within View of the Gentleman's Houſe, probably you will be required to encloſe it with Chineſe Rails; for which Purpoſe, you are to prepare your Poſts as directed in Chap. XIV. Sect. 1. and drive them down by the Sides of the Heads of the Piles; but if it lies remote, you may drive down ſtrong rough Stakes, and plat them with the Branches, for this is only a temporary Work, and there ought not to be much Money expended on it, becauſe, if it conquers, and effectually keeps off the Water, the Gentleman, or the Public, or both, may be, perhaps, better accommodated with a ſubſtantial Road, or Imbankation. After you have fully conſidered the next Propoſition, or by the Directions formerly given for Quay Walls, you may build a double Wall

on

on the reclaimed Side, at any convenient Diſtance, and this will perhaps, effectually keep the Water off from you in the mean Time; but let us alſo ſuppoſe, and lay down Methods for making a ſubſtantial Turnpike Road, through a ſhaking Bog, which may happen to intervene, and erect Forts or other weighty Building in the ſame.

SECT. II.

The Method of making a ſubſtantial Turnpike Road, through a quaking Bog of 15 *Feet deep, and to erect Forts or other weighty Stone Buildings in the ſame.*

WE are informed that many ſuch Roads have been made by the antient *Romans*, ſome to the extent of ſeveral Miles in Length; but in our poor Country, we have no right to pretend to copy after them; but as Neceſſity is the Mother of Invention, let us try if we can contrive to form a Method of accompliſhing a Work of this Nature, which is ſo abſolutely neceſſary, not only for the reclaiming ſome of our Bogs, but alſo for the uniting the Neighbourhoods of two fertile Countries, that at preſent ſeem as remote from one another, as if they were in different Climates. As for Inſtance;

Between two very populous Countries, we will ſuppoſe, there lies a Valley of many Miles in Length, the greateſt Part of which is liable to be covered with Water in the Winter; and even in the Summer, it is ſuch a quaking Bog, as deters either Man or Beaſt from venturing upon it: The Public have therefore, taken it in Hand and reſolved,

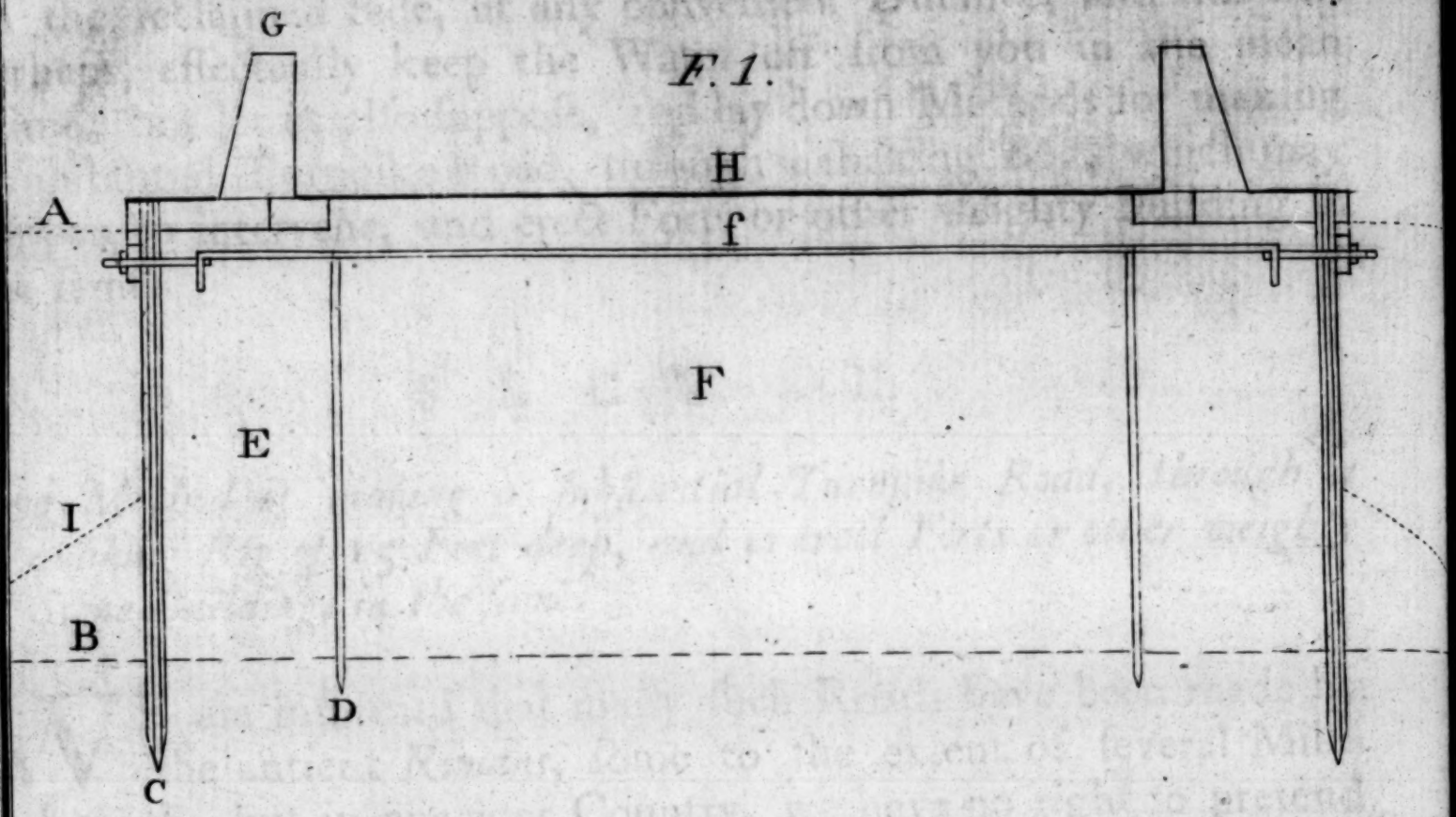
PROP. IX. *To make a ſubſtantial Turnpike Road, through a ſhaking Bog of* 15 *Feet deep, to be incloſed with parapet Walls of rough Stone and Lime, of five Feet high on each Side, and* 30 *Feet broad in the clear. In Summer Time, this Bog is generally covered over with a Scraw, or Scurff of moſſy Graſs, under which the Slutch is ſo exceeding ſoft, that a Stone of one Pound Weight will meet no Oppoſition, till it ſinks to the Bottom, which is a ſtiff ſandy Marl.*

Surely,

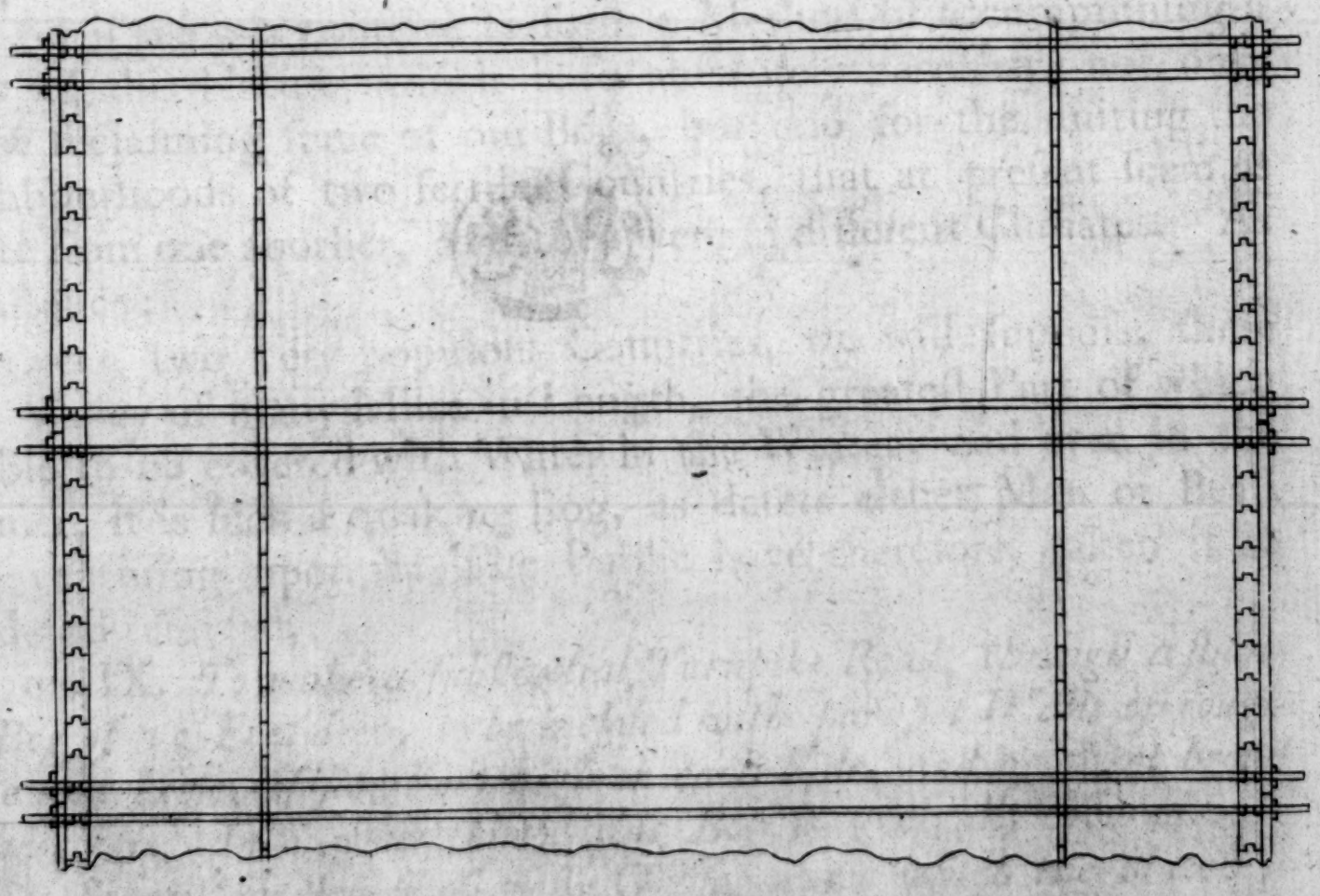


Pl. 41.

F. 1.



F. 2.



Surely, you muſt allow, that above all other Works, thoſe that are done by the Public, ought to be performed after the moſt ſubſtantial and durable Methods: Let us therefore, now conſider how this Work may be ſo accompliſhed. See

METHOD. PLATE XLI. *Scale* 8 *Feet to* 1 *Inch.*

Fig. 1. Exhibits the Section of the Road. Wherein note, A. Is the Surface of the Bog. B. The Bottom of it. C. The Dovetail Piles that form the Coffer. D. Temporary Piles or Planks that are to ſeparate the Stuffing. E. The Coffer for the Walls; and F. the Coffer for the Road. E. is to be ſtuffed with ſmall Stones, Lime and ſharp clean Gravel, as before directed; but F. is to be ſtuffed or filled with the hardeſt gravelly and ſtony Stuff, you can conveniently get. Then the Planks D. are to be drawn up, as of no further uſe in that Place; becauſe the Stuff that is to make the Road, would not by any Means be ſufficient for the Foundations of the Parapets. And you ſee the ſtuffing E. is to be covered over with cut Stones of 4 by 2 Feet, and a Foot thick; and hence you ſee the Parapets are battered to 18 Inches thick. The ſtuffing of both E. and F. will ſettle conſiderably, but they will ſettle perpendicularly, and drive and diſperſe the Slutch of the Bog before them; and according as you find them ſettle, you muſt ſtill continue to fill them up from Time to Time, as Occaſion may require. f The Chain that braces them all together. G. Parapet Wall. H. Surface of the Road, which you ſee is here ſuppoſed to be but one Foot above the Surface of the Bog. I. Is the Banks which are to be raiſed at Diſcretion according as you go on, to help to Buttreſs and Brace in the Piles that form the Coffer.

Fig. 2. Is Part of the Plans of the Coffers, with the Situation of the Braces. In which obſerve, that the Braces are placed together in Pairs, which may have about ten Piles between each Pair, as before directed in Plate XXXIV. Fig. 2.

I do not pretend to ſay, that this Method is entirely of my own Invention, but to my Succeſs in conſulting ſeveral antient Hiſtories, wherein I found ſufficient Matter, together with what

I have before mentioned, for my grounding this Contrivance, not only for the preſent, but alſo the following Propoſition upon. And notwithſtanding I take great Pains to be conciſe, yet, I ſhall refer you to one particular Place, which you will find abridged in *Chambers*'s Dictionary, under the Article of Road, which I before mentioned, and as that Book may not be in your Hands, I ſhall here tranſcribe exactly what he ſays.

" Road, an open Way or Paſſage, forming a commodious " Communication between one Place and another.

" The *Romans* of all People took the moſt Pains in their Roads. " The Labour and Expence they were at, to render them ſpacious, " ſtreight and ſmooth, are incredible.---Uſually they ſtrengthened " the Ground by ramming it, laying it with Flints, Pebbles, or " Sand; ſometimes by a lining of Maſonry, Rubbiſh, Bricks, " Potſherds, *&c.* bound together with Mortar.

" *F. Meneſtrier* obſerves, that in ſome Places in the *Lyonnois*, he " has found huge Cluſters of Flints cemented with Lime, reach- " ing ten or twelve Feet deep, and making a Maſs as hard and as " compact as Marble itſelf, and which, after reſiſting the Injuries " of Time for 1600 Years, is ſtill ſcarce penetrable by all the " Force of Hammers, Mattocks, *&c.* and yet the Flints it con- " ſiſts of, are not bigger than Eggs."---Pleaſe to obſerve, that this coroborates with the former Accounts given of the petrifying Qualities of theſe Materials.

I do not ſay that this Road of ours, will be as firm and as ſubſtantial as theſe *Roman* Roads, becauſe we only purpoſe to ſtuff the Coffers on which the parapet Walls are to ſtand, with thoſe choice Materials; but I affirm, that if we were able to go to the Expence of ſuch a Work, and this Bog was 20 or 30 Feet deep, it is practicable to make a Road through it as firm and as compact as theirs; becauſe I am ſure our Country abounds with as good Materials for that Purpoſe, as perhaps, any other produces, except the principal Material, *Money*, to carry on ſuch a Work.

But notwithſtanding our great Scarcity of this principal Material in all Works, yet Matters, perhaps, might be ſo managed, as to carry on a uſeful Work of this ſort at a very moderate Expence;

and

and here we have a fair Opportunity to introduce one of the Methods I pointed out, in the latter End of the ſecond Section of the laſt Chapter, which I adviſe you to recall to your Mind, and I ſhall now enlarge a little further upon it.

If ſuch a Road is to be made through ſuch a ſhaking Bog, you are to make ſuch Coffers as is therein before directed, and exhibited in Plate XXXI. and throwing out the Slutch, &c. build a ſlender Pier in each of them of rough Stone, for about a couple of Feet above the Surface, and thereon to turn ſlight rough Stone, or hard Brick Arches, agreeable to the extent of your Deſign; and as you go on, draw up the Piles and apply them to the next Piers in like Manner, as alſo therein before mentioned; and to facilitate the Work, you may have ſeveral ſets of ſuch Piles. If Stones are ſcarce and Timber plenty, you may make a ſubſtantial temporary Cauſey over the Piers, but by all Means I would prefer the Arches.

It is well confirmed that numerous ſuch Cauſeys, have been made through Moraſſes by the Antients, and that ſome of them have extended to eight Miles in Length, and thirty Yards in Breadth.

Numerous Forts and other ſumptuous Edifices, have likewiſe been erected by them in Moraſſes; but the Conciſeneſs of this Work, will not admit of my tranſcribing Abſtracts from them. Let it therefore ſuffice, that I here briefly point out one of the Methods which I firmly believe muſt have been the Method practiſed by ſome of them. And I alſo conclude may moſt readily be executed at a very moderate Expence by us alſo. As for inſtance:

Let us ſuppoſe, that you are required to preſcribe quick and cheap Methods for building a ſubſtantial Foundation for a Fort, or any other weighty Building of Stone and Lime of 200 Feet ſquare, or any other large Extent, in a Moraſs or quaking Bog of 15 Feet deep, on a penetrable Clay or loamy Bottom.

Having thoroughly examined the intended Scite, and prepared Plans and Materials for the Purpoſe, by this *Method* (ſo fully explained above) you are to erect a competent Number of Pillars of ſtrong rough Maſonry, ſuppoſe of eight or ten Feet ſquare, and perhaps eight, ten or fifteen Feet Diſtance from each other, and thereon turn ſegment Vaults and Arches, which will give you a

Platform, whereon you are to erect the intended Building, always paying due regard to the Pillars throughout the Superſtructure. This Method is ſo eaſily underſtood, that I need neither form any Deſigns, nor enlarge any further on it.

But I ſhall give you another Inſtance, in which this ſort of Coffer Work may alſo in many Caſes be ſucceſsfully applied, and have alſo been probably made uſe of by the Antients, in making inland Navigations through their Moraſſes.

SECT. III.

Coffer Work applied to the making of a navigable Canal, through a ſhaking Bog 15 Feet deep.

THE Valley before-mentioned, extending on almoſt a dead level, for great Part of the Space between two navigable Rivers, with ſeveral opulent Market-towns adjacent; we will ſuppoſe, that the Public have alſo taken in Hand, to turn the ſame to a national Advantage, and reſolved,

PROP. 10. *To make a navigable Canal* as a Communication between thoſe Rivers, through the moſt convenient Parts of the Valley. You are, therefore, required to lay down ſure, quick and cheap Methods to carry ſuch a Canal *through Part of a ſhaking Bog, fifteen Feet deep*, as before. See

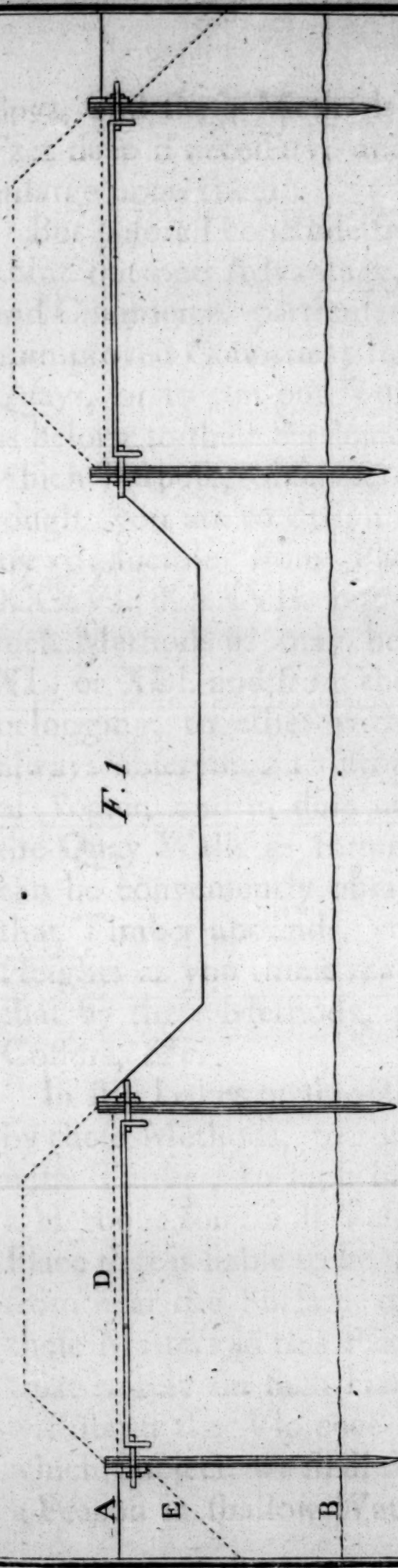
METHOD. PLATE XLII. *Scale* 12 *Feet to* 1 *Inch.*

Fig. 1. Repreſents a Section of the Canal. Wherein note, A. Surface of the Bog. B. Bottom of the ſame. C. Dovetailed Piles that form the Coffers, after the Manner of Figure 2, 3 and 4, in Plate XXXI. D. Brace-bars, Chains, or Scantling, and E. Bank, which is to be raiſed at Diſcretion.

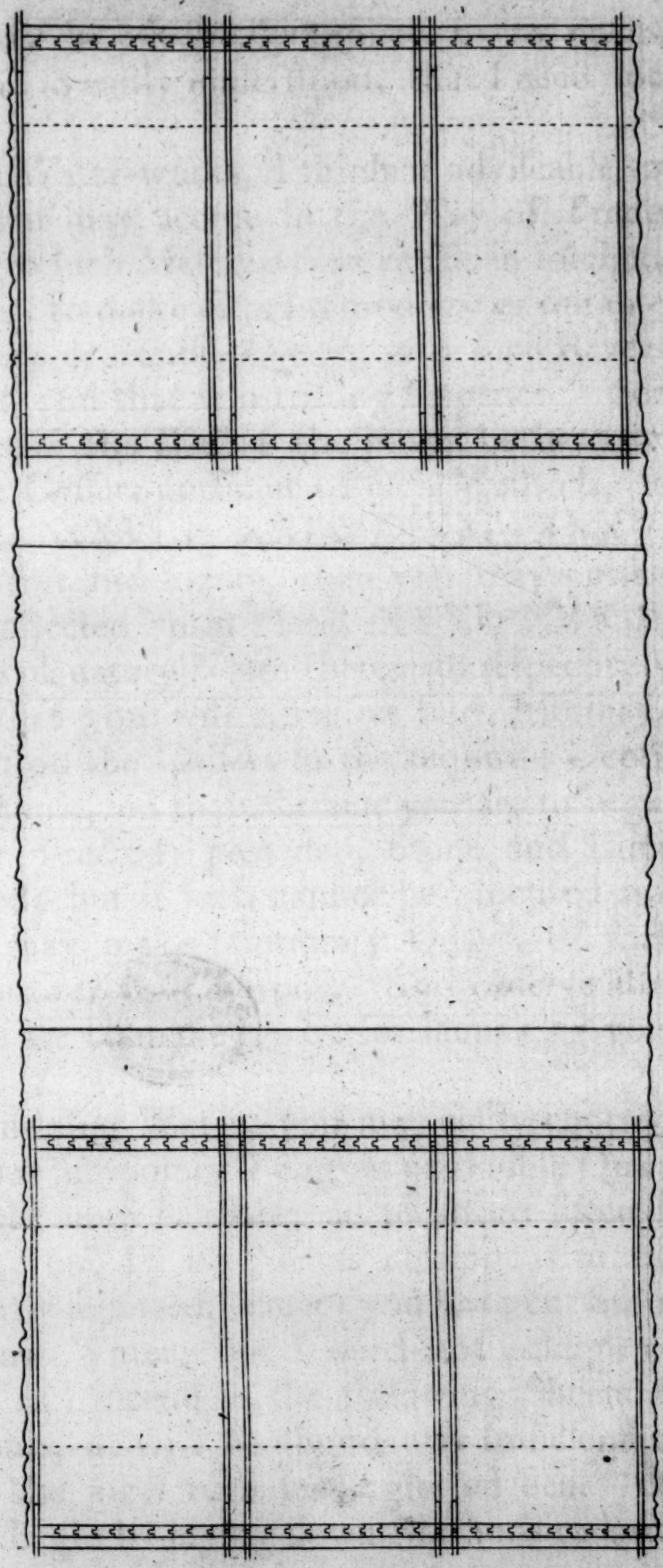
Fig. 2. Repreſents the Plan of the ſame, ſhewing the four Rows of Piles, Chains, Ribbons, *&c.*

Theſe laſt two Propoſitions, if properly attended to, may alſo be productive of ſure and effectual Methods of reclaiming extenſive Bogs,

Pl. 42.



F. 1



F. 2.

Bogs, and theſe Methods may be effectually applied to 20 or 30 Feet deep if neceſſary, and are ſo eaſily underſtood, that I need not enlarge upon them.

But before I conclude freſh Water-works, I think it adviſeable to point out one Advantage, that may accrue in the Way of Trade and Commerce, particularly to ſuch Merchants as traffic in foreign, unimproved Countries; that is, to make either temporary or durable Quays, or to run out Tongues or double Quays, into ſuch Rivers as belong to their Settlements, and that at a trifling Expence. For which Purpoſe, obſerve, that if the Bed of the River be hard or rough, you are to deſign the Coffers purſuant to ſuch Methods, as are deducible from Plates, XXVIII. XXIX. XXX. XXXV. XXXVI. XXXVII. but if ſoft and loamy, then you may purſue ſuch Methods as may be collected from Plates XXXI. XXXIII, XL. or XLI. and from the explanatory Notes thereunto reſpectively belonging, together with what you will hereafter find deſcribed; always obſerving, to proportion the Coffers to the requiſite Depth of Water, and in durable Work, on theſe Coffers you are to begin the Quay Walls as formerly directed; provided, Stone and Lime can be conveniently obtained; but if ſuch cannot be procured and that Timber abounds, you may make temporary Quays, of ſuch Heights as you think may anſwer your Purpoſe: And obſerve alſo, that by theſe Methods, you are to make Quays for launching your Coffers, *&c.*

In ſtill Lakes or ſmooth running Water, you may eaſily contrive by theſe Methods, to run out temporary Tongues or double Quays with Timber, to ſuch Height and Lengths, as to afford likewiſe a Harbour for ſmall Veſſels; but by no Means attempt it in any Place that is liable to be greatly agitated, except you have cut Stone from near the Surface of low Water; but I need not enlarge on theſe Matters in this Place, as I intend in the following Sheets to treat largely on ſuch Harbours, as will be abundantly ſufficient to withſtand the Violence of the moſt turbulent agitated Sea. On which Subject, we ſhall firſt begin by laying down Methods to build a Beacon in ſhallow Water.

CHAP.

CHAP. XVII.

Coffer-work applied to Buildings, that may be thereby effectually executed in the Sea.

I HAVE had very little Acquaintance with Marine Affairs of any kind; and therefore, I preſume, I may hope to meet with ſomewhat of Indulgence in my treating on Things of this Nature, and alſo for your own friendly Endeavours to aſſiſt me, in hopes of bringing theſe important Matters to ſome Maturity; as I have already inſinuated, that there are but few Arts or Sciences, that have been brought to Perfection, by the utmoſt Endeavours of the firſt Contrivers of them.

It is now upwards of 23 Years, ſince I firſt obſerved the Petrifactions mentioned in Chap. VI. Sect. 2. and from that Time to this, I have applied my feeble and utmoſt Abilities, in endeavouring to turn and improve my Obſervations to the real Advantage of the Public in general; and I think, it would be inexcuſable to ſmother or conceal the Notions that occurred thereupon. But I entreat a patient Attention to what I am now about to mention, and I hope that my Plans and Deſigns will not be condemned as impracticable, until the real Merit of them are thoroughly weighed and conſidered; though I muſt confeſs, that if ever you have ſeen the Sea in a violent Storm, as I have ſeveral Times obſerved with a trembling Heart, I ought not to wonder at your entertaining ſome Doubts of Succeſs, but at the ſame Time do not forget, that the Sea is not at all Times ſo violently agitated; and therefore, let us endeavour to contrive ſuch ſure Methods as may reaſonably promiſe Succeſs, and be accompliſhed with great Expedition, at any Time when a favourable Opportunity offers; for it is not the Sea alone that you have to encounter with, but the moſt aſtoniſhing and dreadful Effects of the Tides and Winds.

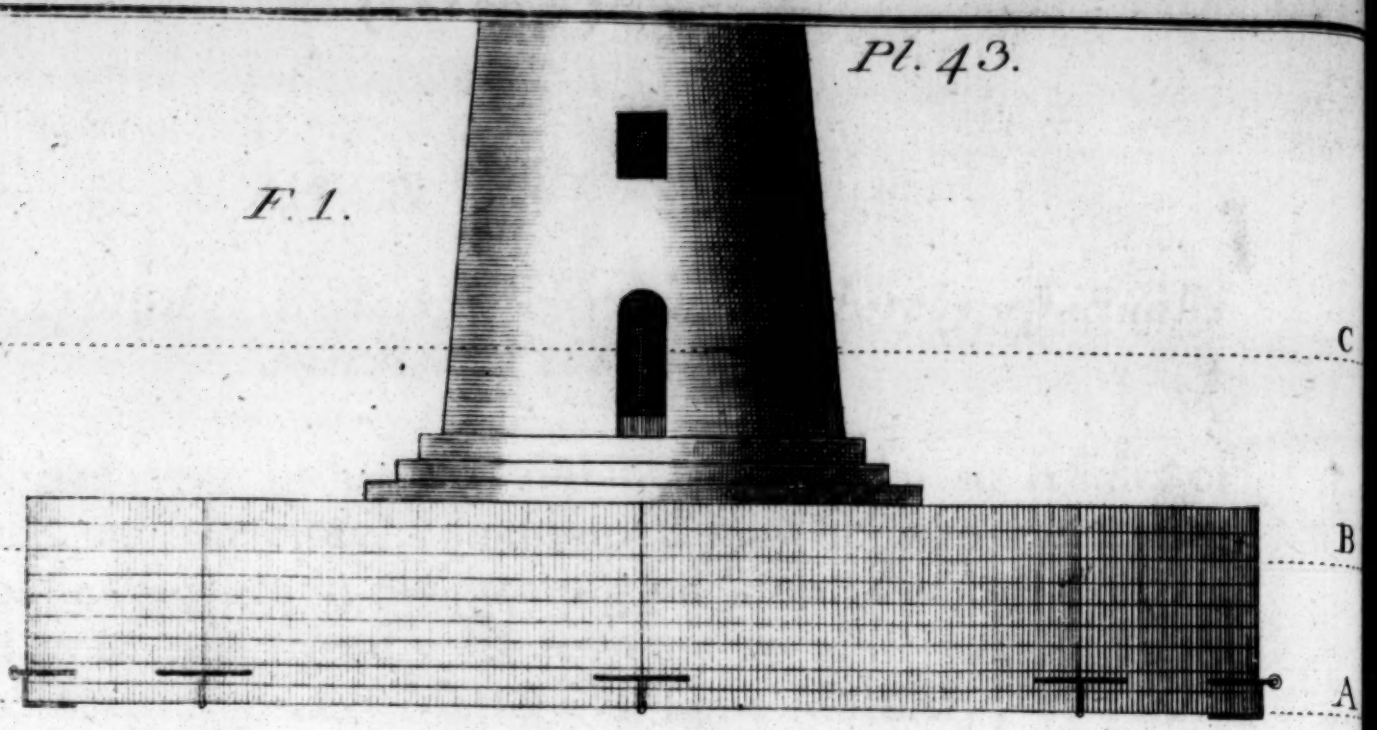
As to the ebbing and flowing of the Tide, we are moſt comfortably circumſtanced; for, generally ſpeaking, we can tell to wonder-

ful

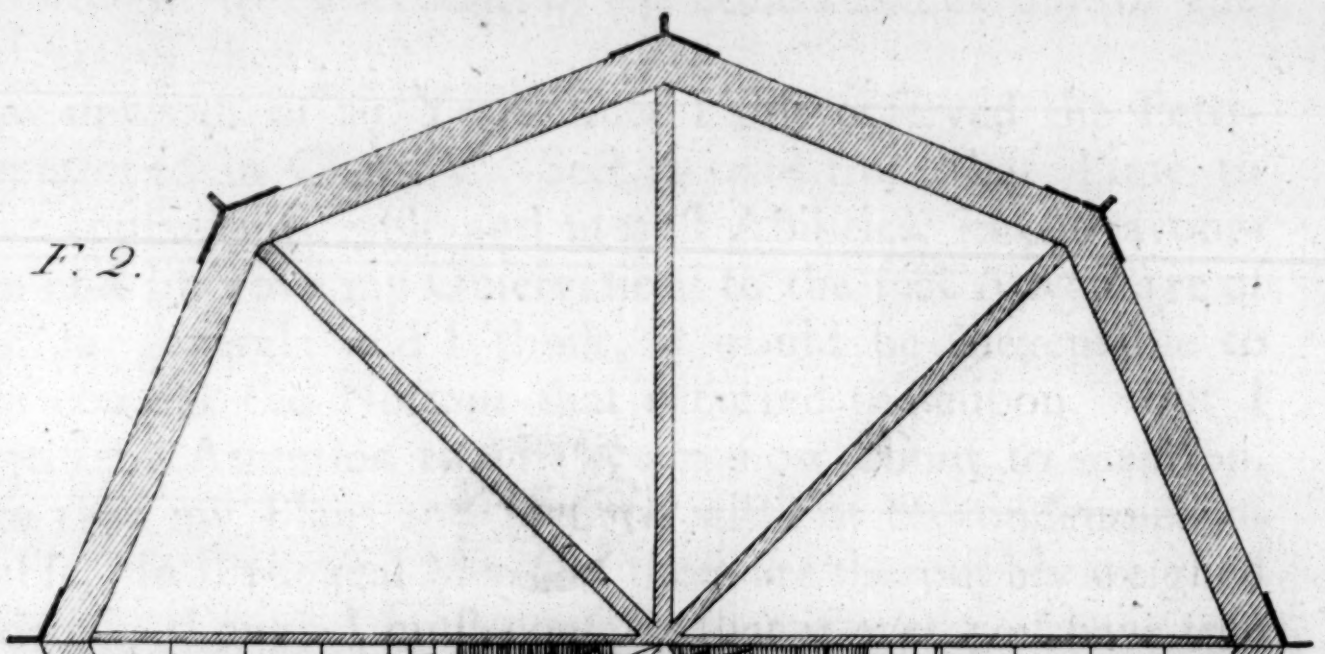


Pl. 43.

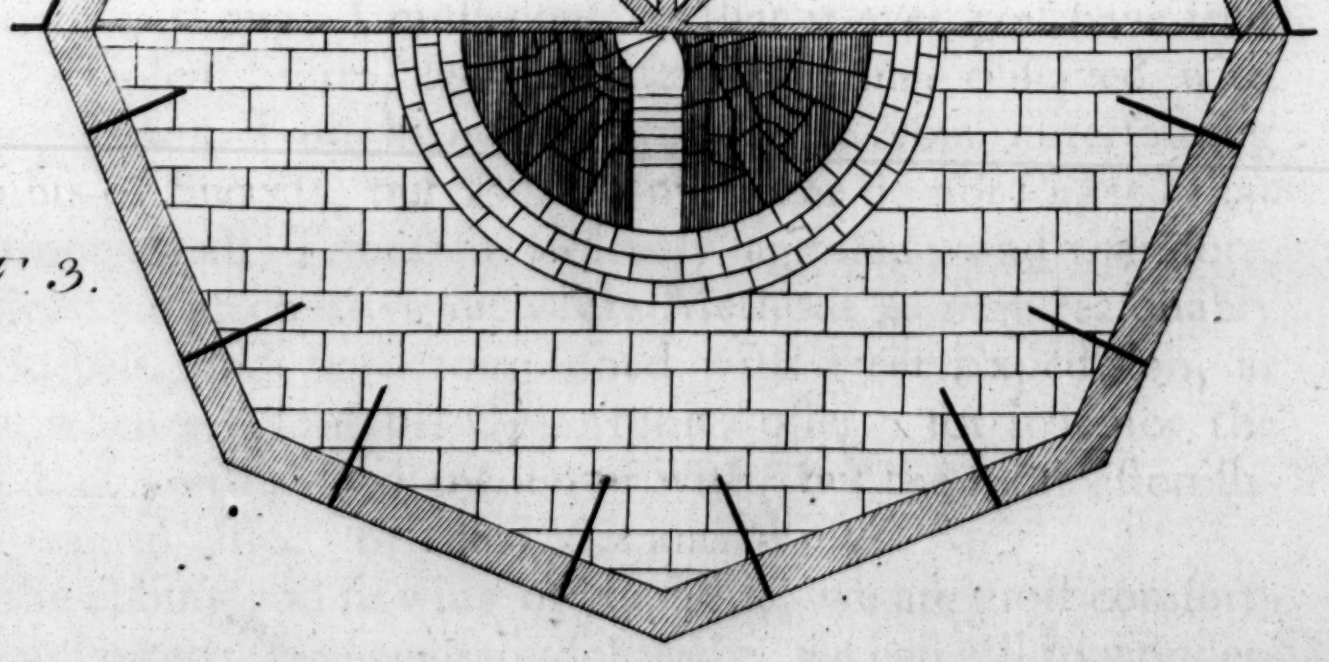
F. 1.



F. 2.



F. 3.



ful exactneſs, when it will flow, and when it will ebb; when we may expect high Tides, and when we may hope to have low ones. But I believe no Man has been able to tell preciſely the Height that ſome ſpring Tides may riſe to, nor the Height and Power of the Winds when united with them. In this Caſe, therefore, you muſt paint to your Imagination, the moſt powerful Effects of them you can poſſibly conceive, and deſign your Work after ſuch firm and ſubſtantial Methods, that it may be able to withſtand their utmoſt united force: And in order to exert our beſt and utmoſt Endeavours, let us begin with a ſmall Beacon, or Light-houſe, before we attempt the more weighty Matters intended.

SECT. I.

Concerning the building of a Beacon, or Light Houſe in the Sea.

PROP. XI. *TO build a ſubſtantial Stone and Lime Beacon, or Light Houſe of 20 Feet Diameter in the Sea, the dead low Water being about eight Feet deep; and ſpring Tides ſometimes riſe ten Feet more.*

METHODS *laid down in* PLATES XLIII. XLIV. XLV. *and* XLVI. *Scale* 12 *Feet to* 1 *Inch.*

Plate XLIII. Fig. 1. Furniſhes you with an Idea of the Land-front of the lower Part of the Light-houſe, ſtanding, as it were, upon the Coffer, ſtuffed and floored as formerly directed. Wherein note, A. Bottom of the Water. B. Low-water mark. C. High-water mark. Fig. 2. Shews the Ground-plan of the principal Timber of one half of the Coffer, excluſive of the Grating. Fig. 3. Repreſents the Surface of the other half of the Coffer, floored with the Cut-ſtones, and cramped as before directed; and alſo, the Plan of the lower half of the Light-houſe, which is to be wrought ſolid with cut and large ſcabbeled Stones, except the Stair-caſe.

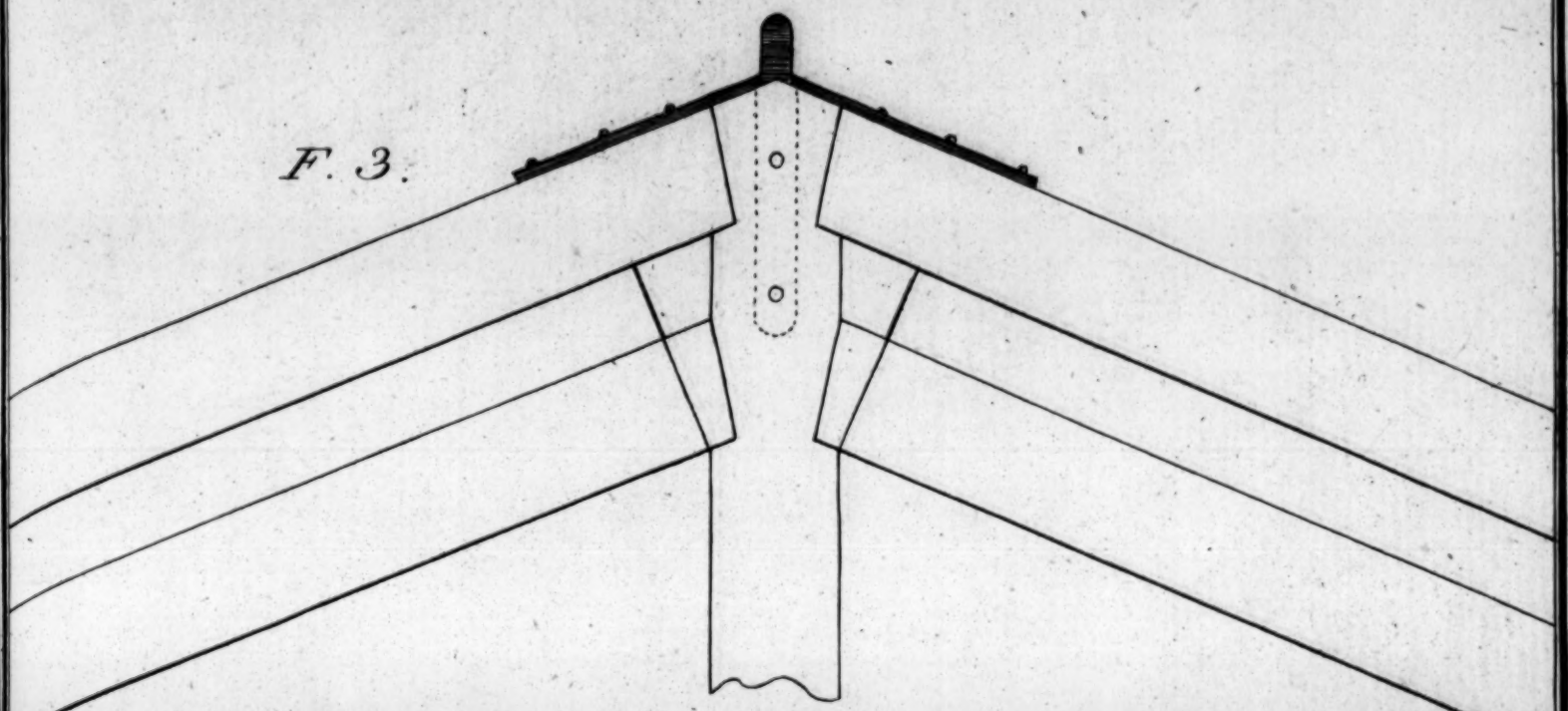
Plate XLIV. Fig. 1 and 2, (*Scale* 12 *Feet to* 1 *Inch.*) Shews the principal Timber and the Grating. In which obſerve, that all the principal

principal Timbers are to lie exactly over one another, and ſo are all the extreme Timbers that ſurround them. Fig. 1. Repreſents half of the 1ſt Courſe, and Fig. 2. half of the 2d Courſe, which together make the Grating or Bottom two Feet thick, in both of which, the principal, or diagonal Beams, are to extend 60 Feet 8 Inches; four Inches being allowed for the ſet-off, that is to be on the 2d Courſe: And as you cannot get Timber of 60 Feet long, you are to take particular care that the Timber of the 2d Courſe, ſhall break Joints with the Timber of the 1ſt Courſe, and that they be both firmly ſpliced and bolted together, to prevent their wrecking, ſwagging or diſlocating by any Accident or Miſmanagement in the launching of the Coffer. And beſides theſe Iron Bolts, there muſt be an Abundance of Oak Keys, both through the principal and through all the outward Timbers. By Oak Keys, I mean, that you ſhould get a competent Number of Pieces of Oak tried up, of about 2 Feet long, 9 Inches broad and 4 thick, each. The Mortices for them, muſt be made quite through each Piece, and exactly anſwerable to each other; and theſe Keys muſt be drove into the Mortices, and pinned with Oak Trundles of about full Inch Diameter, ſo as both the under and upper Courſes of all theſe principal and outward Timbers, may be firmly united together. And you ſee that between theſe outward Timbers in each Courſe, there is to be a Vacancy of eight Inches, and in this Vacancy the upright Piles are to ſtand, which Vacancy, and the Manner of framing the diagonal and outward Timbers together, you may ſee laid down in Fig. 3. (*Scale* 2 *Feet to* 1 *Inch*) and when theſe two Courſes are compleatly united together, you are then to put on your angular Plates on the upper Courſe, and in Caſe you have no Sea-braces, then each of theſe Plates are to have three Wings, two of them are to encompaſs the Angle, and the third is to go underneath the End of the diagonal Piece, with two Bolts through each of thoſe Pieces, as you ſee marked out in dotted Lines. The Neck that proceeds from theſe three Wings muſt be of about the Subſtance of full three Inch ſquare Iron at the leaſt, with either a Hole, or a Ring, to receive the buoy Ropes, as has been formerly directed;

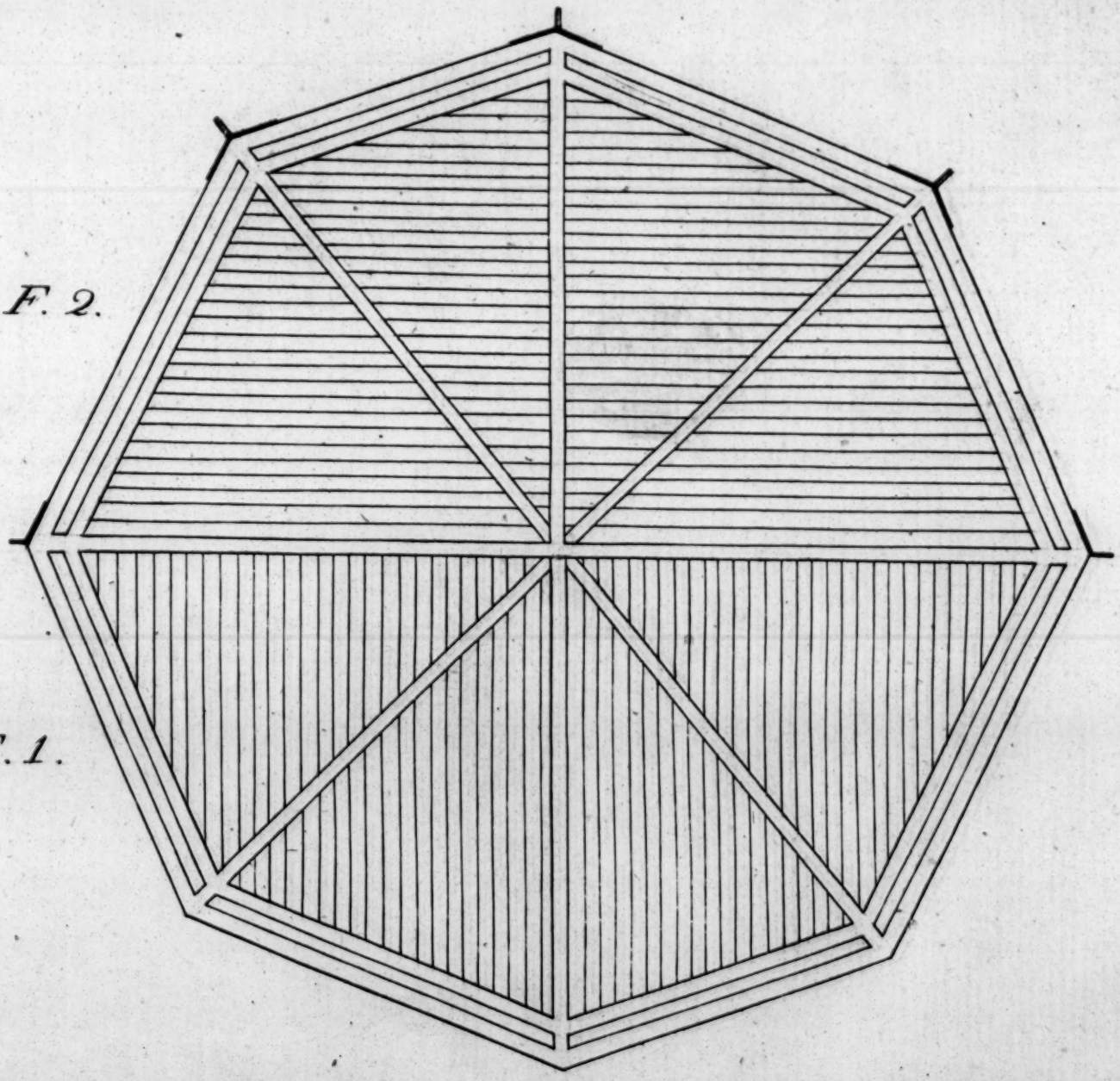
and

Pl. 44.

F. 3.



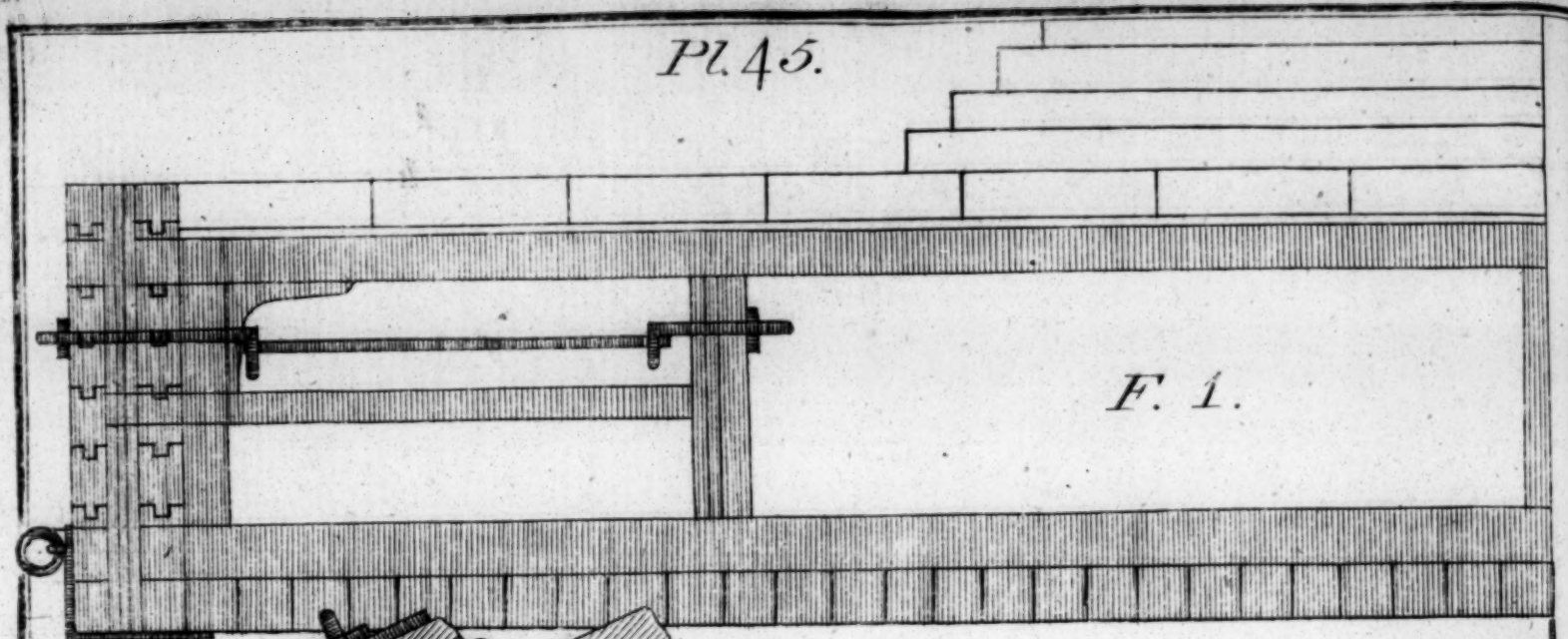
F. 2.



F. 1.

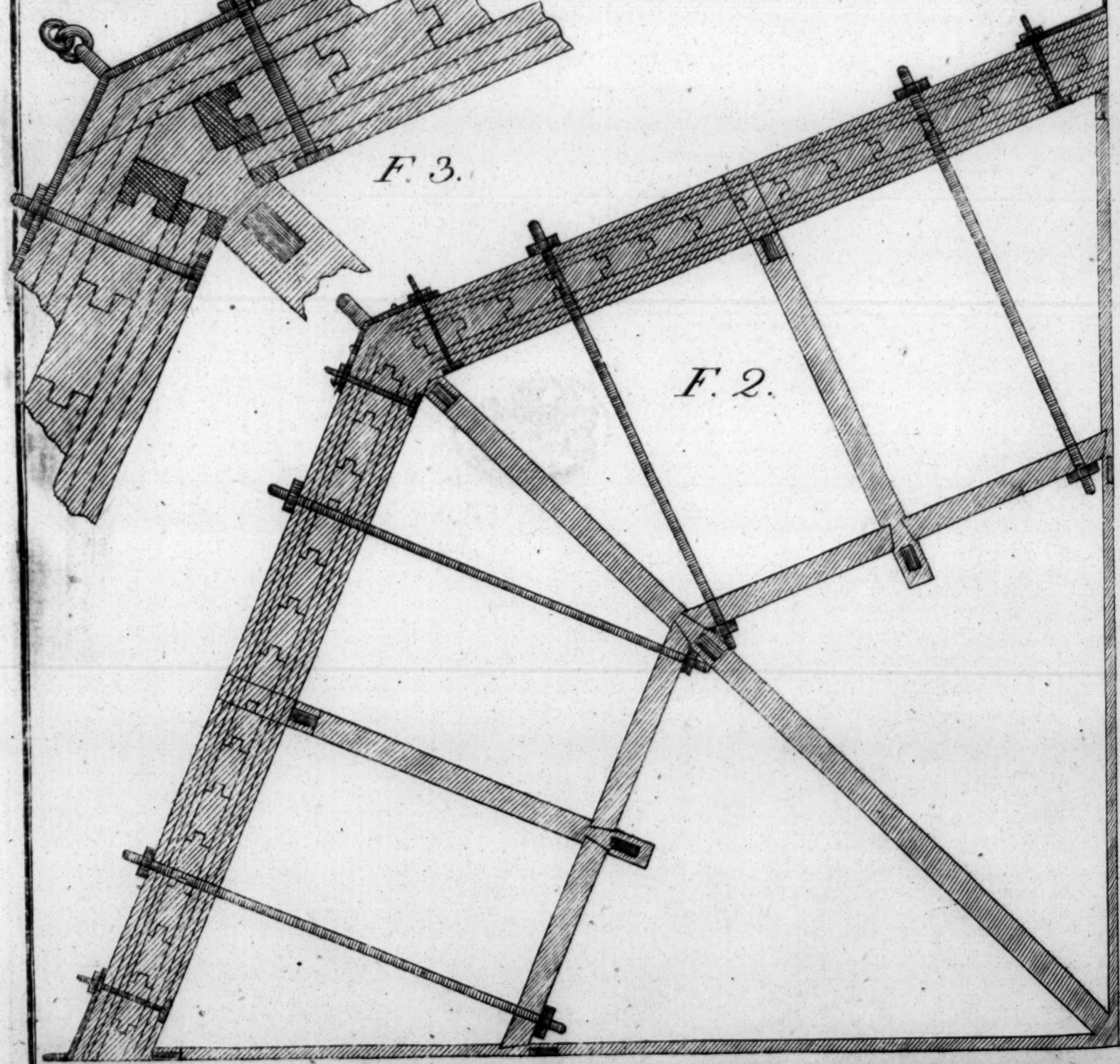
BRITISH MUSEUM

Pl. 45.



F. 1.

F. 3.



F. 2.

and if you have Sea-braces, you will find them deſcribed in their proper Place.

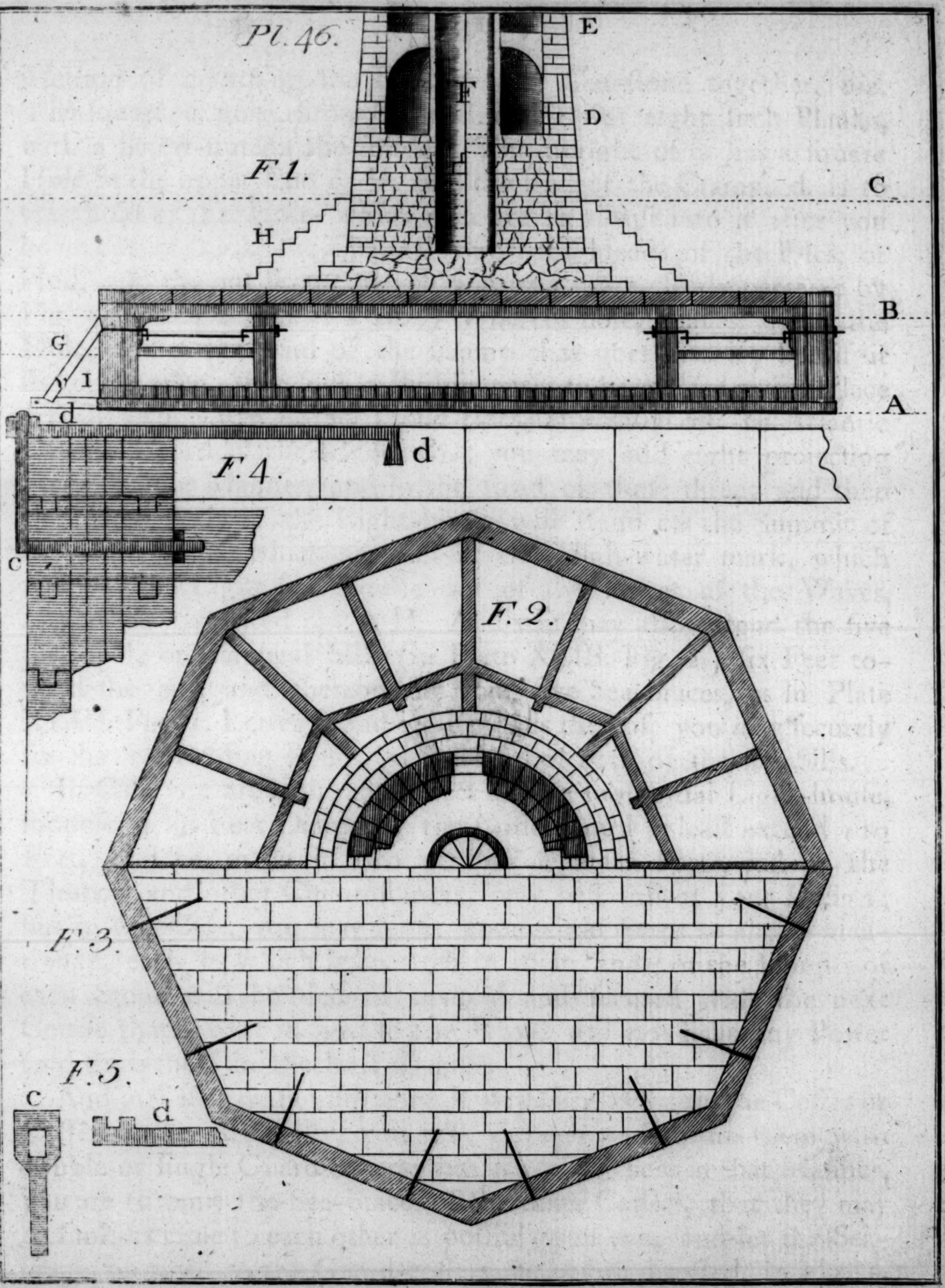
Plate XLV. Fig. 1. *Scale* 5 *Feet to* 1 *Inch.* Is the Section of one quarter of the Coffer, as if it was compleatly ſtuffed, with the cut Stone Floor, and the four firſt Courſes of the Light-houſe built upon it. Fig. 2. (ſame Scale) is the Plan of the upper Timbers of that Quarter, with the Brace-bars and other Iron Work. Fig. 3. *Scale* 2 *Feet to* 1 *Inch.* Shews you how the three Rows of Piles are united together. You ſee that the Hull is compoſed of three Piles or Planks of eight Inches thick each, and their Breadth at Diſcretion. They are all to be tongued and grooved as formerly directed, and firmly pinned and bolted; the three Piles taken together, making, as it were, one ſolid Thickneſs, of which the middle Row (as you may ſee by the Section of the Hull, Fig. 1.) is the Tennon, and goes down two Feet between the outward Timbers, which are the Baſe of the Hull; through each of which outward and inward Pieces, and through each of the upright Piles, there are to be Oak Trundles drove, of an Inch and a half Diameter. In this Fig. 3. you alſo ſee the corner Poſts, into which the diagonal Pieces are to be double dovetailed; and alſo, the Tongues of the two next upright Piles are to be let into Grooves, which you are to prepare for them therein, and ſo are the Ends or Tennons of the inſide horizontal Piles alſo. Theſe corner Poſts are to be made of Oak, in two Parts, which are to be firmly keyed and bolted together, after you have made all the Grooves and Dovetails belonging to them; and you muſt recollect the Vacancy left between the out-ſide Timbers in the laſt Plate, and make two Tennons in the Foot of this Oak Poſt, or double Poſt, exactly to fit and ſtand in the Vacancies, one on each Side, to fit the dovetail of the diagonal Beam, in which two Places they are to ſtand, as it were, on two Legs aſtride the diagonal Beam, wherein they are to be ſecurely bolted. And I muſt repeat, you are not to forget, that in the Middle of the Interſection of all the upright and level Piles in the Hull, there are to be Inch and half Oak Trundles drove tight through them, and wedged in the inſide. Every Pile of the outſide is to be dovetailed at the Angles, like ſo many Belts,

to confine the whole Hull together, and you ſee how the Iron work is to be applied thereto; but you muſt alſo ſtrictly obſerve, that all the Tongues and Grooves, both in the upright and level Piles, are to be done after a Workman-like Manner, ſo that the fineſt Particle of the Sand, or even the Lime-water, may not be ſucked out through them by the Waves. Indeed the Joints in the Bottom may be an Inch wide, becauſe when it is launched, it will let the Water into it, which will help to ſink it, and the finer Particles of the ſtuffing will ſoon fill them all up, of which you muſt here allow an extraordinary Proportion, and the Bank will ſecure them all.

Plate XLVI. Fig. 1. *Scale* 12 *Feet* 1 *Inch.* Repreſents the Section of the whole Coffer, as if it were ſtuffed and floored with Cut-ſtones; and the Section of the lower Part of the Light-houſe, as if it were ſtanding upon it. Wherein note, A. The Bottom of the Water. B. Low-water mark. C. High-water. D. The firſt Floor of the Light-houſe. E. Part of the ſecond Floor. F. Well-hole of the Stairs; and G. The Bank to be raiſed at Diſcretion; but ſtrictly obſerving not to let any Stone exceed a Handful in your banking: Becauſe, a large Stone is to the Waves, as a large Tree is to the Wind, which will give great Oppoſition to it, when at the ſame Time it will paſs gently over diminutive Shrubs; which is evident by the Breakers on the Strand. Beſides, large Stones make large Cavities, and large Cavities contain large Quantities of Water, and large Quantities of Water operate much more powerfully than ſmall ones, which I ſhall demonſtrate hereafter.

Fig. 2. (by the ſame Scale) Shews you the Plan of the upper Timbers of the Coffer, the Plan of the Stairs, and the firſt Floor of the Light-houſe, with the circular Bar that is to be let into that Courſe. Fig. 3. Repreſents the Platform or Surface of one half of the Coffer, ſtuffed and floored with the Cut-ſtone; and the eight ſtrong Lines repreſent the Cramps, which muſt be made of 1 $\frac{1}{2}$ Inch ſquare Bar, and ſunk ſomething more than their full Depth into the Stones, ſo that the melted Lead will entirely cover them, and when they are eaten with ruſt, they are eaſily replaced, or more added if neceſſary. Fig. 4. *(Scale 2 Feet 1 Inch.)* Shews you the Method

Pl. 46.



F. 1.

F. 4.

F. 2.

F. 3.

F. 5.



Method of cramping the Hull and the Cut-ſtone together, *viz.* The ſquare c. goes through the three Piles or eight Inch Planks, with a Screw-nut on the inſide. The upright of c. has a ſquare Hole in the upper End of it; and the End of the Cramp, d. is to take hold of that Hole, which you are to thruſt into it after you have cut or ſunk the Channel acroſs the Heads of the Piles, or Hull, and the cut Stone, which you may more clearly perceive by Fig. 5. (*Scale* 2 *Feet to* 1 *Inch*) Wherein note, that c. ſhews the Hole, and d. the End of the Cramp that goes into it; but if it ſhould happen, that ſuch a Building was to be erected in any Place greatly expoſed to ſtormy Flood-tides, eſpecially off the Atlantic Ocean, I particularly adviſe, that you may add eight projecting Steps in like Manner, and in the ſtead of thoſe three; and then the naked Body of the Light-houſe will ſtand on the Summit of the eight Steps, which are juſt at the High-water mark, which will put the Light-houſe quite out of the Power of the Waves, as you ſee it marked out at H. And you may alſo extend the five principal, or diagonal Sills (in Plate XLIII. Fig. 2.) ſix Feet toward the Sea, and thereon fix your five Sea-braces, as in Plate XLVI. Fig. 1. Letter I. and on the Ends thereof, you may ſecurely fix the five hauling Rings, at the End of each of the five Sills.

In Caſe you are required to erect a more ſubſtantial Light-houſe, ſuppoſe of 40 Feet Diameter, the Coffers muſt at leaſt extend 120 Feet, and be made in two or four ſeparate Parts, juſt as the Timber, and other Circumſtances, may beſt anſwer your Deſign; but in this Caſe, you may ſet it upon eight Steps as above mentioned, each of which is an Arch in itſelf, and $\frac{3}{4}$ of the Length of each Stone will be tied in covered and ſecured with the next Courſe that is over it, and ſo the Waves will not have any Power to diſturb them in the leaſt Degree.

And in Caſe you ſhould think it neceſſary to ſecure the Coffer or Coffers more effectually, you may environ and ſecure them with double or ſingle Guard-coffers; but if you do them in that Manner, you are to omit the Sea-braces of the inner Coffers, that they may be ſunk as cloſe to each other as poſſibly you can; and let the Sea-braces be fixed to the Guard-coffers, as before directed, in Fig. 1.

Letter I. Obſerve alſo, that in ſtuffing the Coffers in the Sea, you muſt be much more liberal in the Proportion of Lime, than what we concluded upon for freſh Water-works, becauſe it will be in much more danger of being both waſted and weakened; therefore, if you can procure Lime at a moderate Price, beſtow it bountifully on ſuch Work as theſe; for it is the Lime alone, that creates the Petrification, and by all Means, that ought to be promoted. And if I have been too penurious in proportioning that expenſive Article, let your own Diſcretion, tempered with a little experimental Knowledge, conduct you therein.

I am confident, and I hope it has appeared evident, that this petrifying Quality is moſt aſſuredly one among numerous other moſt uſeful Properties, peculiar to Lime-ſtone; but how this petrifying Quality is to be heightened or haſtened in freſh and ſalt Water, that indeed, is not within my ſcanty Province to determine; therefore, I moſt humbly beg leave to recommend it to the ſtudy of curious philoſophical Gentlemen, acquainted with the Qualities and Operations of Compounds, as I preſume there is a great Probability, that theſe my poor Gleanings may be thereby brought to Maturity, and that by an induſtrious Cultivation thereof, they may be rendered productive of Utility in Matters of ſuch exceeding great Moment to the Public in general. There are many other Things neceſſary to mention, but you will find them diſperſed through the following Pages.

SECT. II.

Concerning the building of a Stone Pier in the Sea.

PROP. XII. *TO build a ſingle Pier-head of Cut-ſtone in the Sea, the dead low Water at neap Tides being* 20 *Feet deep, and high ſpring Tides riſing* 20 *Feet more.*

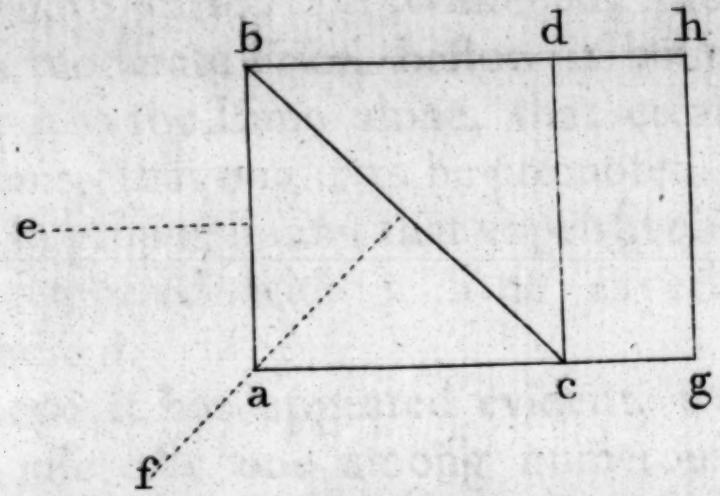
Previous to our forming theſe or the like deſigns, we muſt conſider, that the Tides and the Winds have very powerful Effects, eſpecially when united. Let us therefore, endeavour to find out ſome certain and general Rules for this Purpoſe; in order to which,

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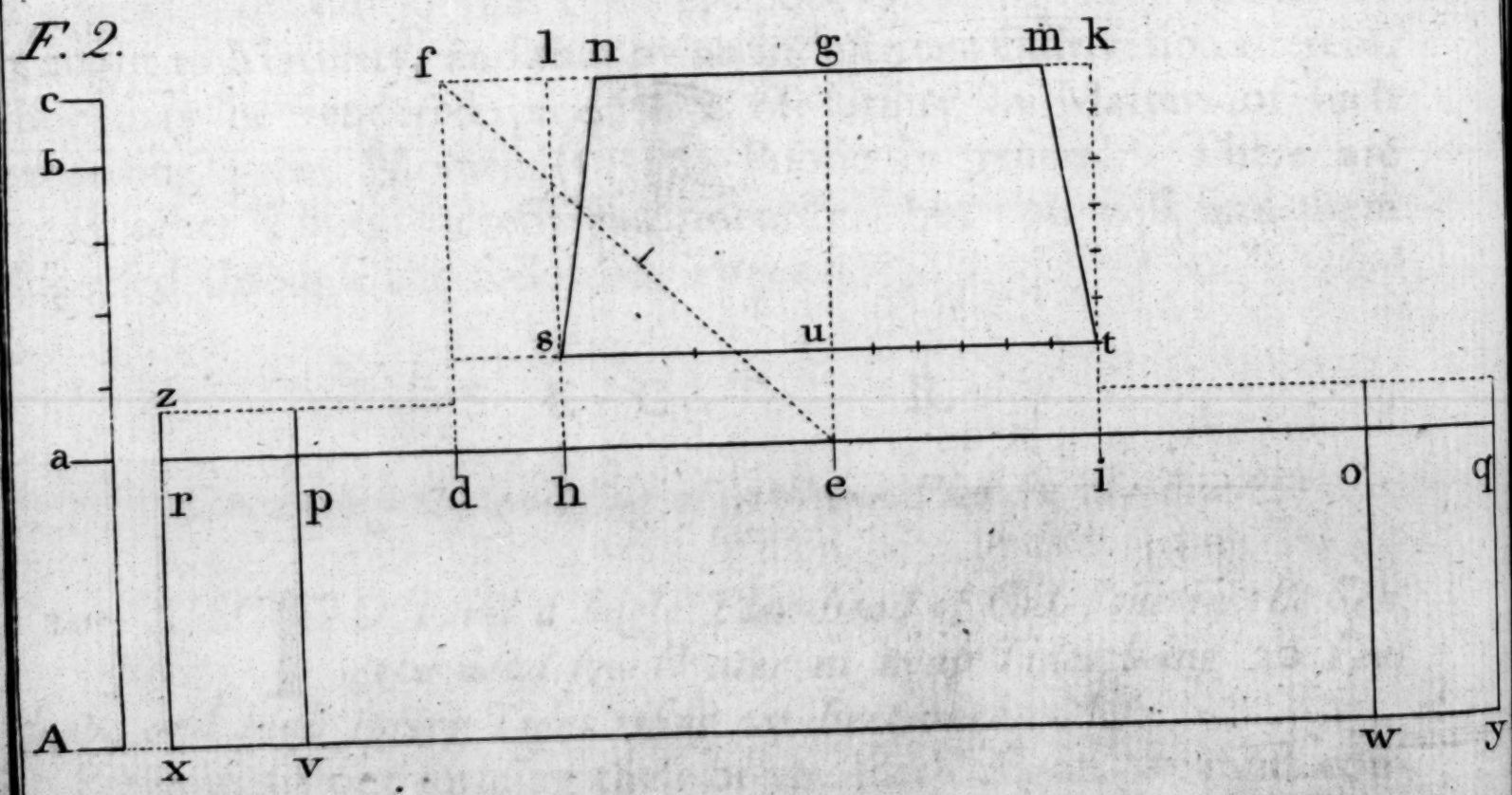
Pl. 47.

F. 1.



F. 3.

F. 2.



it may perhaps, be neceſſary to obſerve, that one cubical Foot of Stone, upon an Average, may be ſuppoſed to weigh three cubical Feet of Water; but Stone being more ponderous, it will conſequently be the more powerful in its Oppoſition, and the fitter for our Purpoſe. Let us therefore conſider, as for inſtance: In a ſtill, quiet Lake, you muſt admit that the whole Weight of the Water, reſts and ſtands upon its own Baſis, that is, the Bottom of the Lake; and the Bank, or whatever the Incloſure of it is, ſuſtains very little Preſſure by that Water. Let us now ſuppoſe, that Part of this Lake is incloſed with a perpendicular Line of 20 Feet high; which is the Height here given for the Tide. See Plate XLVII. *Scale* 16 *Feet to* 1 *Inch.* which Line is repreſented in Fig. 1. by the Line, a. b. Now if you were required to form a Brace, or rather a Stone Buttreſs, to ſtrengthen, and give that Line ſufficient Power to keep its perpendicular Situation, ſo as to be able to ſupport itſelf and to ſuſtain the Preſſure of that Water, to the Extent and Height of twenty Feet, you muſt lay down another Line of the ſame Length horizontally, and in right Angles with it, as, a. c. and then draw the hypothenuſe, or diagonal Line, b. c. which diagonal Line, b. c. deſcribes the Bounds and Power of a Stone Buttreſs, which will be abundantly ſufficient to withſtand the Preſſure of this Water, or at leaſt equivalent to it; which you may prove thus. Multiply, a. b. by itſelf, the Product will be 400, and a. c. by itſelf, the Product will be 400 more, add theſe two together, and they will be 800; then take off your diagonal Line, b. c. and by your Scale, you will find it near 28 Feet 4 Inches; and multiply that by itſelf alſo, and it will be equal to the Products of a. b. and a. c. taken together, inſignificant Fractions excepted; whence I think it is evident, that the Power of the Line, b. c. is equal to the Powers of the Lines, a. b. and a. c. and conſequently deſcribes the Buttreſs required for a ſtill dead Water.

But now comes on the main Thing. We are not to encounter with a ſtill dead Water, but with the Tide, which is liable at all Times to join in Conjunction with moſt powerful ſtormy Winds; but ſtill, ſuppoſing that they do not exceed our given Height of 20 Feet, (yet what Strength or Power theſe Winds and Tides may acquire

acquire when united, is not to be eaſily determined) but as I told you before, you muſt form in your own Mind, the moſt powerful Effects of them imaginable, and thence draw your Concluſions, whereon you muſt form your Deſigns; ſo that your Work may be ſo ſubſtantial, as to withſtand their utmoſt united Forces; and always obſerving, in Caſe of any doubt, to keep on the ſure Side, throughout the whole Progreſs of your Works: In order to which, let us return and reconſider the Power which appeared ſo adequate to the Preſſure of 20 Feet high, and 20 Feet broad of ſtill Water. From b. and c. draw two other ſuch Lines, which will meet together in the right Angle, d. which will augment our Figure, and thereby produce an exact Cube of 20 Feet, which of Stone, or our Stuffing, upon an Average, would weigh 464 Tons, one half thereof, being 232 Tons, hath already appeared to be adequate to the Preſſure of the Plain, a. b. which is equal to 20 Feet ſquare; the other half of this Cube, being 232 Tons more, makes up a Power, which will certainly be ſufficient to ſuſtain the utmoſt Force of the Tide and Wind, acting together on the Side of the Cube, a. b.

It is evident, that there cannot be any Rule found out, to determine with Preciſion, the Strength and Powers of the Tides and Winds united. Let us therefore, at preſent, endeavour to exerciſe our Reaſon on the following experimental Suppoſition, *viz.* Let a Coffer of 20 Feet Cube, the given Height of the Tide be made, ſtuffed and floored after the Manner herein before, or after directed, and lodged upon any hard level Ground, on the Strand at Low-water mark, the Wind and Tide coming upon this Cube in any Direction, but ſuppoſe from the point, e. I preſume, that this Coffer will be able to ſuſtain the utmoſt Power and Force of that Wind and Tide, for as long a Time as Fir Timber being ſo expoſed could be expected to laſt; but in the preſent Caſe, I conclude, however, that this cubical Proportion, would be too ſcanty for our Purpoſe, becauſe if the Wind and Tide attack this Cube obliquely, as from the point f. they gain a great Advantage of the Cube, for they will have the Line, b. c. to diſcharge their united Powers upon: And although the point whence the Tide flows may be determined,

yet

yet the Wind is variable, whence it is evident, that you muſt not deſign your Pier upon the cubical, but on the diagonal Proportion. Therefore lay down the Line, b. c. from a. to g. and the Line b. d. is to be extended to h. then draw the Line, h. g. which will augment our Dimenſions to about 28 Feet long, and 20 Feet ſquare, and will contain about 11200 Feet ſolid, at 130 Pounds to the Foot, will contain 650 Tons weight. And ſo your Pier being deſigned on this Proportion, every 20 Feet ſquare of ſuch a Pier, would have at leaſt a weight of 650 Tons to oppoſe the force of the Wind and Tide, that may act upon ſo much of its front; which is a weight ſo exceeding great, that I believe there is no conſiderate Man, but what muſt allow that this Proportion will be abundantly ſufficient, but this ſhall be more fully demonſtrated in its proper Place.

Now on theſe Principles, let us proceed to deſign, and conſider the Conſtruction of the Body of the Pier; that is, from the given Low-water, to the Surface, or Bottom of the Parapet. See Fig. 2. (by the ſame Scale) whereby the given Heights are repreſented; and note, A. Is the Bed or Bottom of the Water, a. the Low-water mark. b. High-water mark. Divide a. b. into four equal Parts: One of theſe Parts is to be added to a. b. as a moderate Proportion for the Surge, which will then make the Height a. c. = 25 Feet, for the Height of the Body of the Pier. Then (ſee Fig. 3. by the ſame Scale) draw your Baſe Line, a. q. and interſect it with your Center Line, g. e. take the Height, a. c. which is 25 Feet, and add 6 Inches to it for the 24 Joints of Mortar, and ſet it off from e. to d. and thereon form the ſquare, d. e. f. g. from f. to e. draw the Diagonal, f. e. which by your Scale, you will find to be near 36 Feet. This Diagonal may be looked on as a reaſonable Baſe for the naked Body of the Pier, which you muſt divide into two Parts, and lay them down from e. to h. and from e. to i. and ſo having the Baſe and Height determined, draw the parallel Line, f. e.

You are alſo to conſider, that this Baſe Line of the Body of the Pier, cannot begin at h. i. in the Execution of the Work, becauſe the Hull of the Coffer muſt riſe three Feet above this dead Low-

water

water mark, a. And that the three projecting Courſes, on which the Body of the Pier is to ſtand, will take up three Feet more; and for theſe Reaſons you muſt transfer h. i. to s. t. which is to be the naked Baſe of your Pier, and ſubtracting 6 Feet out of h. l. (= 25 Feet 6 Inches, the laſt given Height) there will be 19 Feet 6 Inches remaining for the Height of the naked Body of the Pier. u. g. Which you muſt divide into 6 = Parts, as at t. k. and take one of theſe Parts, and ſet it off from k. to m. and do the like with the oppoſite Side l. n. and this gives you the true batter, or diminiſhing of the Pier; by which Method, you are to cut the bevil Moulds for the Stone-cutters, and the battering Plumbs for the Setters, *&c.* and deducting l. n. and m. k. from s. t. there will remain n. m. = 29 Feet 6 Inches for the Breadth of the Body of the Pier at the Top, juſt under the firſt Courſe of the Parapet, which to avoid Fractions (which are not neceſſary here) we ſhall call 30 Feet, and this furniſhes you with the principal Dimenſions of the naked Body of the Pier; that is to ſay, the Baſe s. t. = 36 Feet, the Height u. g. (you know was 19 Feet 6 Inches, but we ſhall call it) 20 Feet, and n. m. 30 Feet, and ſo 36, 30 and 20, are the principal Proportions for the naked Body of the Pier, for a Flood-tide of 20 Feet, excluſive of the three projecting Courſes and the Parapet, and including the whole together. Remember, that one Foot long of this Pier (which you will find repreſented in Plate XLVIII. Fig. 1.) will contain 817 ſolid Feet, and 20 Feet running Meaſure of the ſame = 16340 Feet, at 130 Pounds to the Foot, will be 948 Tons: And ſo you ſee that every 20 Feet long of the Pier, will have 948 Tons Weight to oppoſe the Power of Wind and Tide, acting upon the front of that 20 Feet long. And this I am ſure will be abundantly ſufficient to oppoſe them; and this Calculation will alſo be uſeful to you in making your Eſtimates, *&c.*

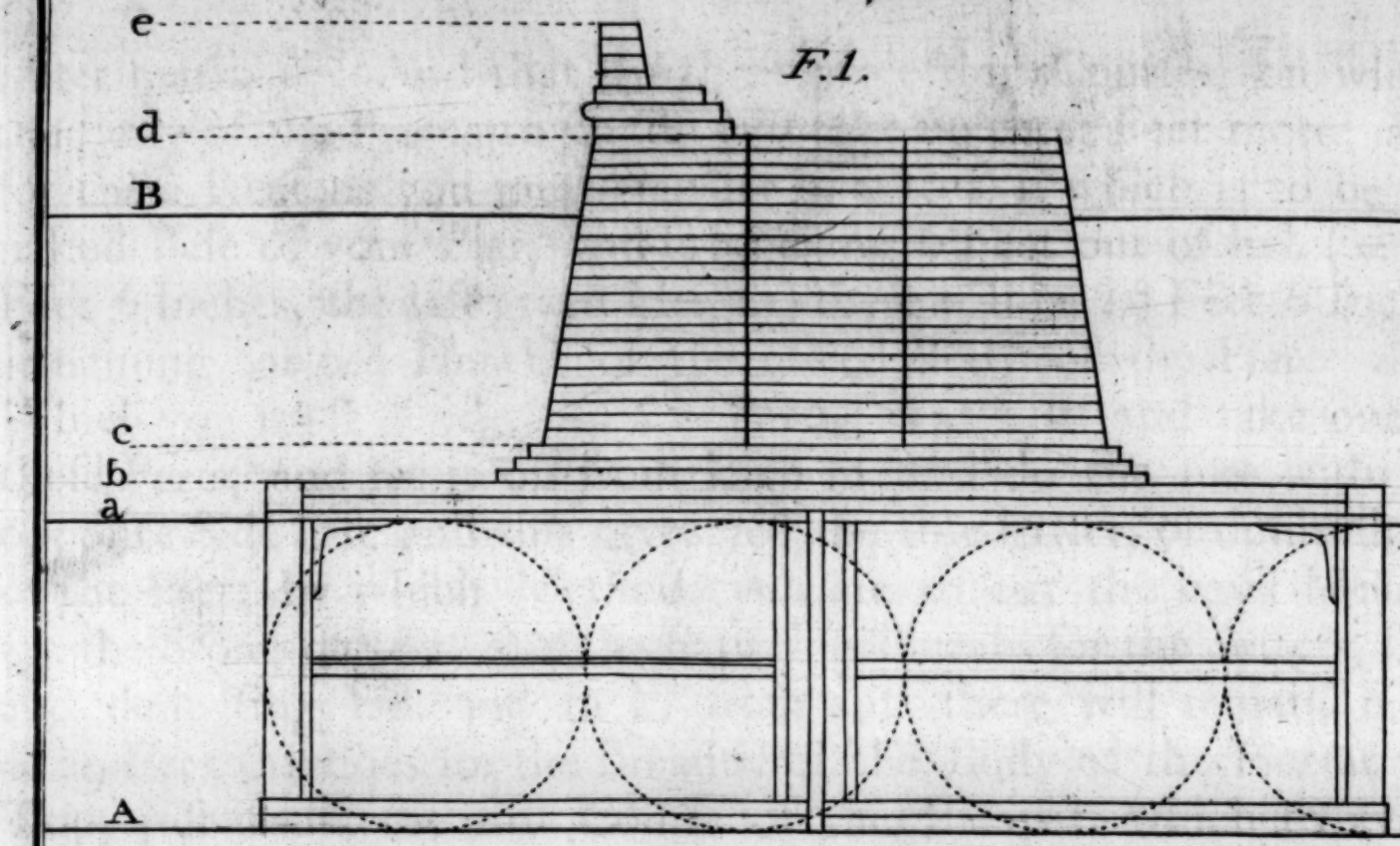
All theſe Matters being ſuppoſed to be clearly underſtood, let us in the next Place, conſider the Proportions of the Coffers for the Body of the Pier. Draw the Line, x. y. parallel to r. q. take the extent s. t. and ſet it off from e. to p. and from e. to o. draw the Lines p. v. and o. w. and p. o. v. w. gives you the Extent of the Coffers for the Pier. Then to proportion the Coffers for a ſingle

Strait-

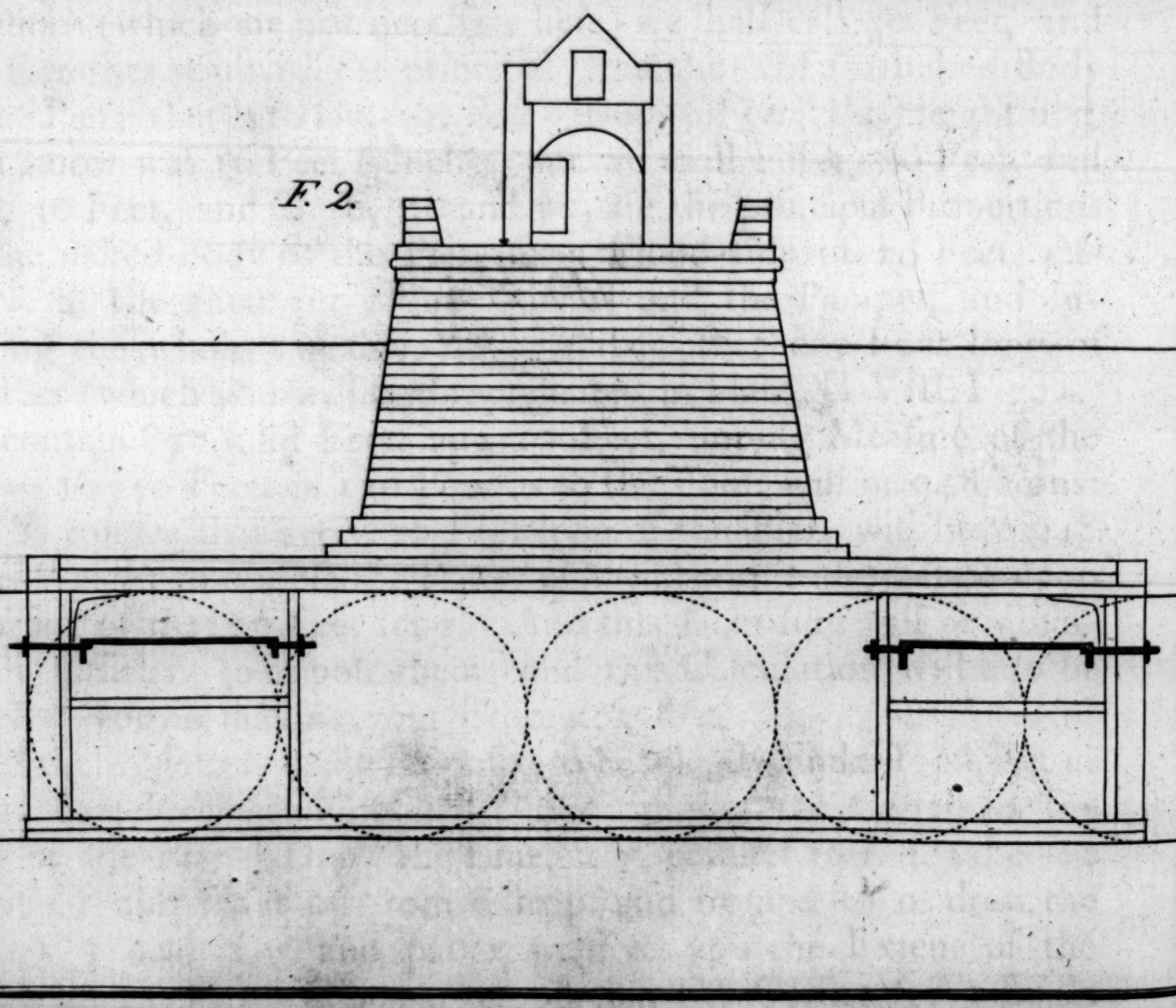


Pl. 48.

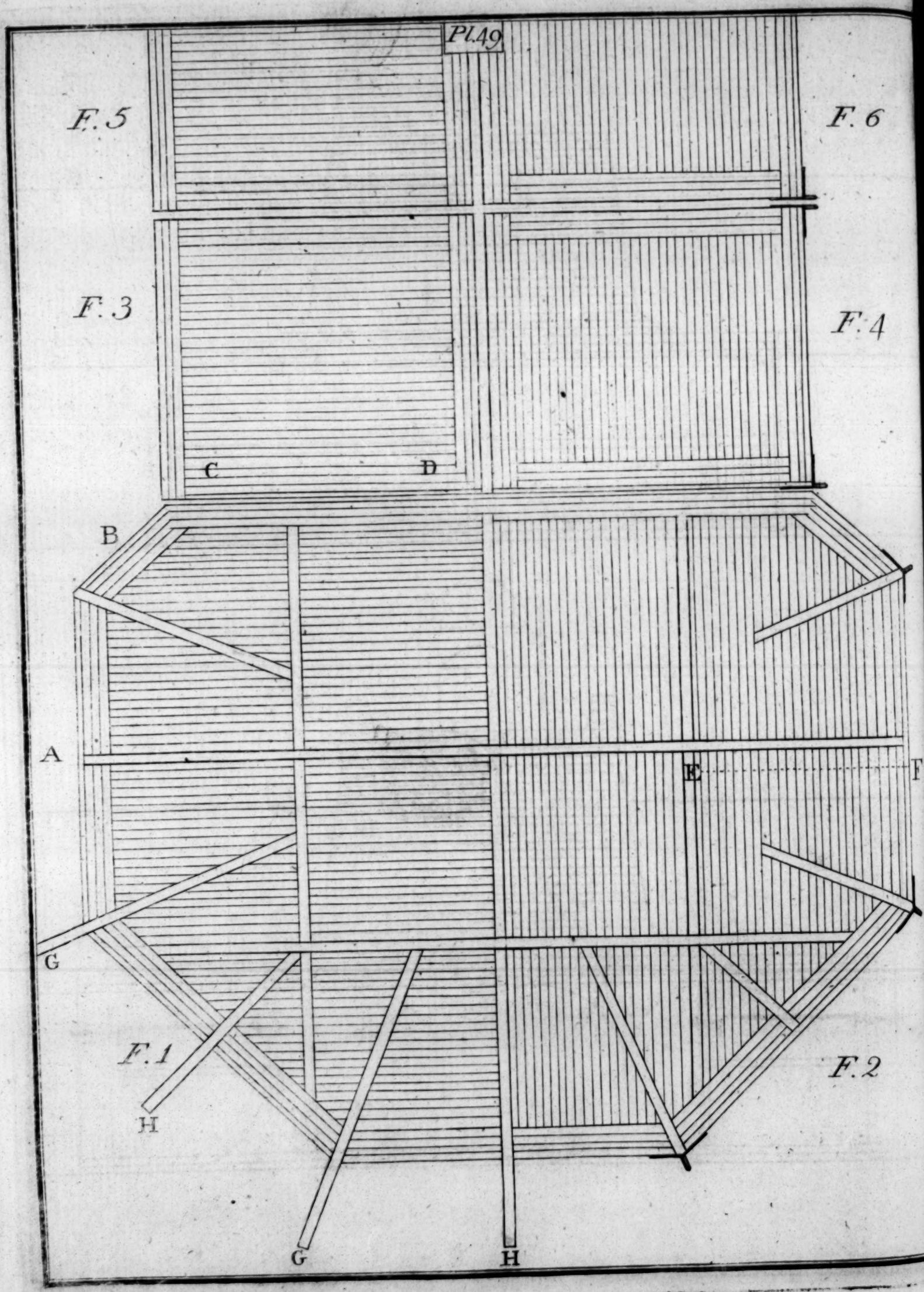
F. 1.



F. 2.



Pl. 49



Strait-pier Head, divide s. u. into two = equal Parts, and lay down one of them, from p. to r. and the other from o. to q. draw the Lines r. x. and q. y. and r. q. x. y. ſhews you the Extent of the inner Coffers for this Pier Head, the Guard-coffers being referred to their proper Place. Then, to determine their Height, divide u. t. into 6 = equal Parts; one of theſe Parts, added to the given Height A. a. gives you x. z. = 23 Feet for the Hull or outward Height of theſe Coffers. Thus you may augment or diminiſh the proportions of your Diagram, according as the various Circumſtances that may attend your Deſign, may reſpectively require. Now let us collect and lay down theſe principal, and the more minute Dimenſions in ſomething of a regular order.

Plate XLVIII. (*Scale* 16 *Feet to* 1 *Inch.*) Fig. 1. repreſents the Section of the Pier compleat, and ſtanding as if it were erected upon its Coffers (which extend three Cubes and a half of Low-water). Wherein note, A. Bottom or Bed of the Coffer. B. High-water. a. Is the Low-water mark. b. The Top of the Hull. c. Baſe of the naked Body of the Pier. d. The Bottom of the Parapet, or Top of the naked Body of the Pier. And, e. (which you ſee alſo comprehends the Plinth and Cord) gives the Height of the Top of the Parapet, which together make 7 Feet or about $\frac{1}{3}$ of Flood-tide, which is a proportionable Height to keep off the Spray; which added to the five Feet before allowed for the Surge, makes 12 Feet above the given Height of a Spring-tide, which you may increaſe or diminiſh at Diſcretion. Fig. 2. Exhibits the Section of the Pier-head, ſtanding upon its Coffer (which extends four Cubes and a half) the Height of which you ſee is the ſame as above. The Superſtructure or ſmall Building on the Pier-head, will be hereafter fully delineated along with the other Parts of the Work.

Plate XLIX. *(by the ſame Scale)* Fig. 1. Repreſents half of the firſt Courſe of the Hull and Grating for the Coffer of the Pier-head. Fig. 2. The ſecond Courſe of the ſame. Fig. 3. The firſt Courſe of one of the Coffers for the Pier. Fig. 4. The ſecond Courſe of the ſame. Fig. 5. and 6. Shew you $\frac{2}{3}$ of the next Coffers for the Pier: On all which I ſhall only now remark, that all the principal Beams in both theſe Courſes, are to lie exactly over one another,

and to be keyed and bolted together, breaking Joints according as the different Length of your Timber will admit, as formerly directed, on the laſt Propoſition.

I have obſerved above, that I am very little acquainted with marine Affairs, and for want of that Knowledge, I muſt confeſs that I am at an èntire Loſs to determine, whether this Coffer for the Head of the Pier, had beſt to be in one or in two ſeparate Parts. You ſee the conjugate and tranſverſe Diameters are equal to about 90 by 76 Feet, which really is an enormous Size: And therefore I ſhall not fully determine this Point; but I adviſe you, that after you are determined as to the Situation of the Pier, and conſidered the various Circumſtances relative to it, you may lay down theſe Draughts by a larger Scale, or make a model of the Coffer by a Scale of one Inch to a Foot, and thereon take the Opinion and Advice of ſome eminent Ship-carpenter, and aſk him this plain Queſtion; Whether it is practicable to launch and ſettle ſo large a Bulk in the Place deſtined for it? And on his, or other Mens Opinions, you may determine this point. For this appears to me the ſole Difficulty, that can in any Ways attend this whole Work; and yet I cannot help thinking, that if it be built in a convenient Place, and a proper Quay made for launching it, as before mentioned, that in one calm neap Tide it may be grounded in its Place, and then all your greateſt Difficulty will be over; but againſt that critical Time, take the utmoſt Precautions to have your Crafts ready loaded, and every Thing neceſſary to crowd in your ſtuffing, to keep it down when it is grounded. But notwithſtanding the Hurry you will at that Time be in, be ſure that your ſtuffing be properly mixed together, for if they throw Stones in one Place, and Lime and Sand in another, the latter will indeed petrify, but the former cannot, which you may eaſily accompliſh by the Precautions I have already given you concerning the ſtuffing. Your beſt endeavours and thoſe of your Workmen, are abſolutely neceſſary at theſe critical Times, in working as the Tide anſwers, both Night and Day, at Night by the help and Direction of your buoy Ropes, till you fill it to the upper Timber.

Upon



Pl. 50.

F. A.

F. 5

F. 3

F. 1

F. 6

F. 4

F. 2

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Pl. 51.

F. D.

c b a

F, B, C & D.

a b c

F. C.

F. B.

a b c d

Upon theſe and other Conſiderations, I have deſigned this Coffer entire, as being by much the more eligible Way; on which you may further obſerve, that part of this Coffer oppoſite to A. is explained in the next Plate. The firſt Courſe of B. C. and D. in Plate LI. The ſecond Courſe of the ſame in Plate LII. And a Section at E. F. Plate LIII. Alſo obſerve, that in Caſe you think it neceſſary to have Sea-braces (as was fully deſcribed Plate XLVI. Fig. 1. Letter I.) you are to extend the four principal or diagonal Pieces, that will be next to the Sea, ten Feet each, as at G. whence ſpring the four Sea-braces; and if you think all that will not be fully ſufficient, you may alſo extend the Ends of the Middle-fills in like Manner, as you ſee at H. H. and let Braces ſpring from them likewiſe.

Plate L. Fig. A. (*Scale* 2 *Feet to* 1 *Inch*) Fig. 1. Shews the Plan of that principal Beam united to the Hull. Fig. 2. Shews the Section of the ſame. Fig. 3. Shews the Plan of the Middle Brace-beam, going through the Hull. Fig. 4. Section of the ſame. Fig. 5. Plan of the upper Brace-beam; and Fig. 6. Section of the ſame, and the Manner of cramping the Hull and the Cut-ſtone together.

Plate LI. Fig. B. C. and D. (*Scale* 2 *Feet to* 1 *Inch*) Fig. B. (as in Plate XLIX.) Shews the firſt Courſe of the Ground-work. Wherein note, a. Out-ſide Timber of a Foot ſquare. b. A vacant Space of 9 Inches wide, left for the Tennon or upright Piles to ſtand in. c. Another Timber of a Foot ſquare. d. The Beam into which the Ends of the firſt Courſe of the Grating is to be let in by a running Mortice; but I believe it might anſwer full as well, and be much more expeditious, and ſave a great deal of Timber, by ſpiking and pinning on four Inch Scantling, to make a Groove for them. And on ſecond Thoughts, I believe that (in Plate XLIX.) it would be adviſable to do the ſame with all the principal Timber in both Courſes of Fig. 1. and 2. Fig. C. Shews the Ground-work of the out-ſide of the Coffer for the Pier. Wherein note, a. Outſide Beam. b. Vacancy for the 6 Inch upright Piles, and c. Inſide Beam. Fig D. Shews the inner Angle. a. Is the Beam. b. Vacancy; and c. Beam, &c.

Plate LII. Fig. B. C. D. *(ſame Scale)* Shews the ſecond Courſe of the Grating, and the Plan of the Hull compleat; but obſerve, that all the corner Poſts, *viz.* a. b. c. are to be made of Oak; and that the ſix Poſts E. are to be made of the ſame in two ſeparate Parts, and bolted and keyed together, as was fully deſcribed in Plate XLV. Fig. 3. with only this Difference; that the Thickneſs of that Hull was three Times 8 Inches, and this three Times 9 Inches.

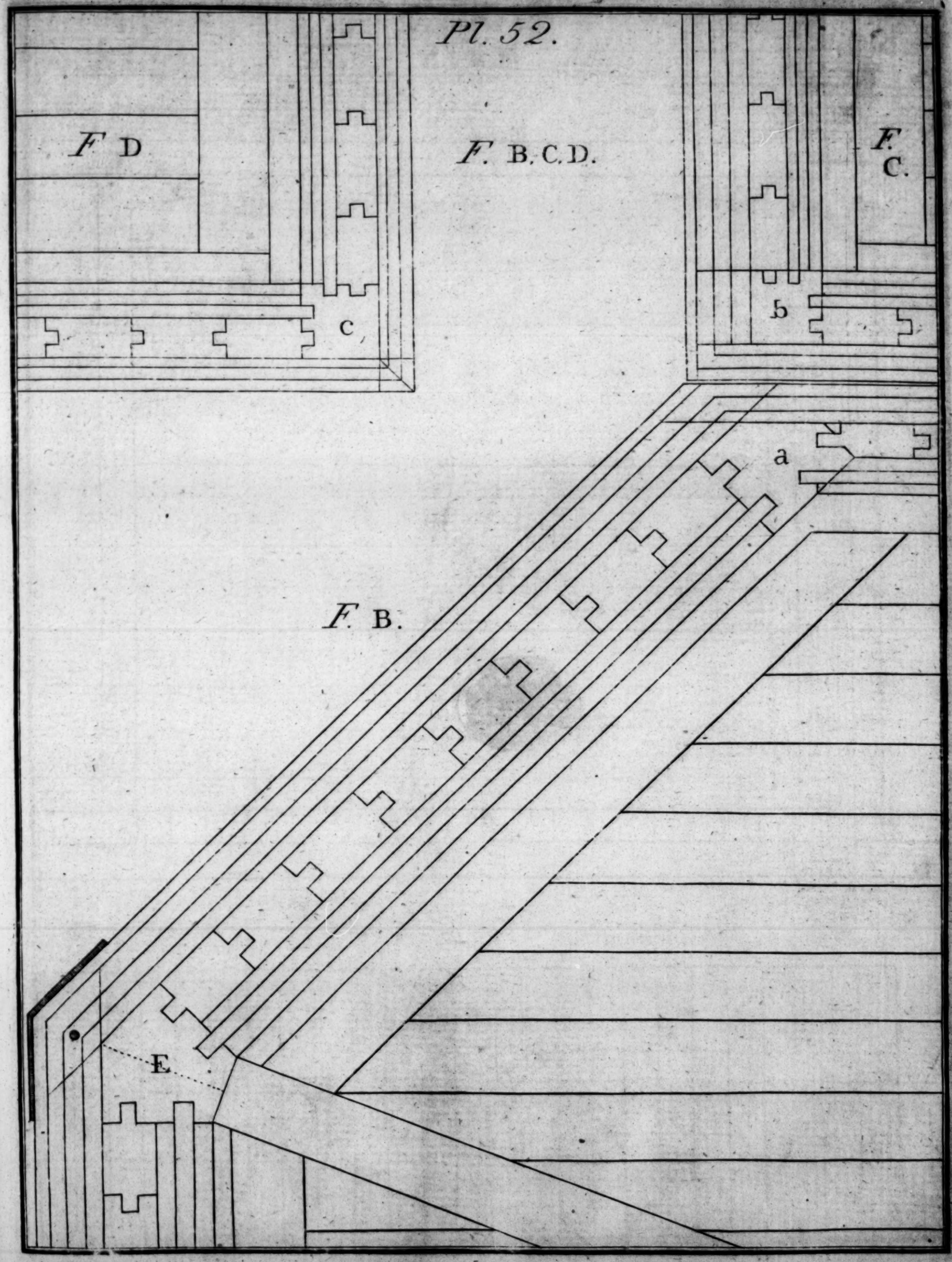
Plate LIII. Fig. E. F. *(Scale 4 Feet to 1 Inch.)* That you may clearly comprehend this Plate, turn back to Plate XLIX. and in Fig. 2. Obſerve the dotted Line E. F. which you alſo ſee here laid down by this Scale, delineating the compleat Section of that Part of the Coffer, with the Plan underneath it, and by your comparing it with Plate XLVIII. Fig. 2. you may fully comprehend the Conſtruction of this Coffer, together with what I've already exhibited. However note, that H. is the Bottom of the Water, and repreſents alſo, the Sill that extends to receive the Sea-braces, provided you have no Guard-coffers. I. The Bank, which you may extend at Diſcretion. K. Is the dead Low-water mark; and L. ſhews the Height and Rake of the Sea-braces, which may be applied here, or reſerved for the Guard-coffers, and may either be double or ſingle, juſt as the Situation, or other Circumſtances may require: And here pleaſe to obſerve, that as you now know the Uſe and Method of making the Sea-braces, you may alſo occaſionally introduce the like in flat-bottomed Coffers; but particularly, they may be of very great Advantage in ſtrengthening, ſuch as are made for Tongues, Quays or the like, either in the Sea or in Rivers.

Plate LIV. *(Scale 16 Feet to 1 Inch)* Gives you the Plan and framing of all the upper Brace-beams, excluſive of the Iron-work, which you ſee applied to the like Purpoſes in Plate XLV. Fig. 2.

Plate LV. *(ſame Scale)* Repreſents theſe Coffers compleatly ſtuffed and floored with the Cut-ſtone, and cramped with Iron; in which remember, that every Cramp muſt extend to the ſecond Courſe of Stone at the leaſt, and when this Work is ſo far accompliſhed, you may proceed with the reſt of the Coffers of the Pier, and leave the Coffers of the Pier-head in this ſecure Condition,

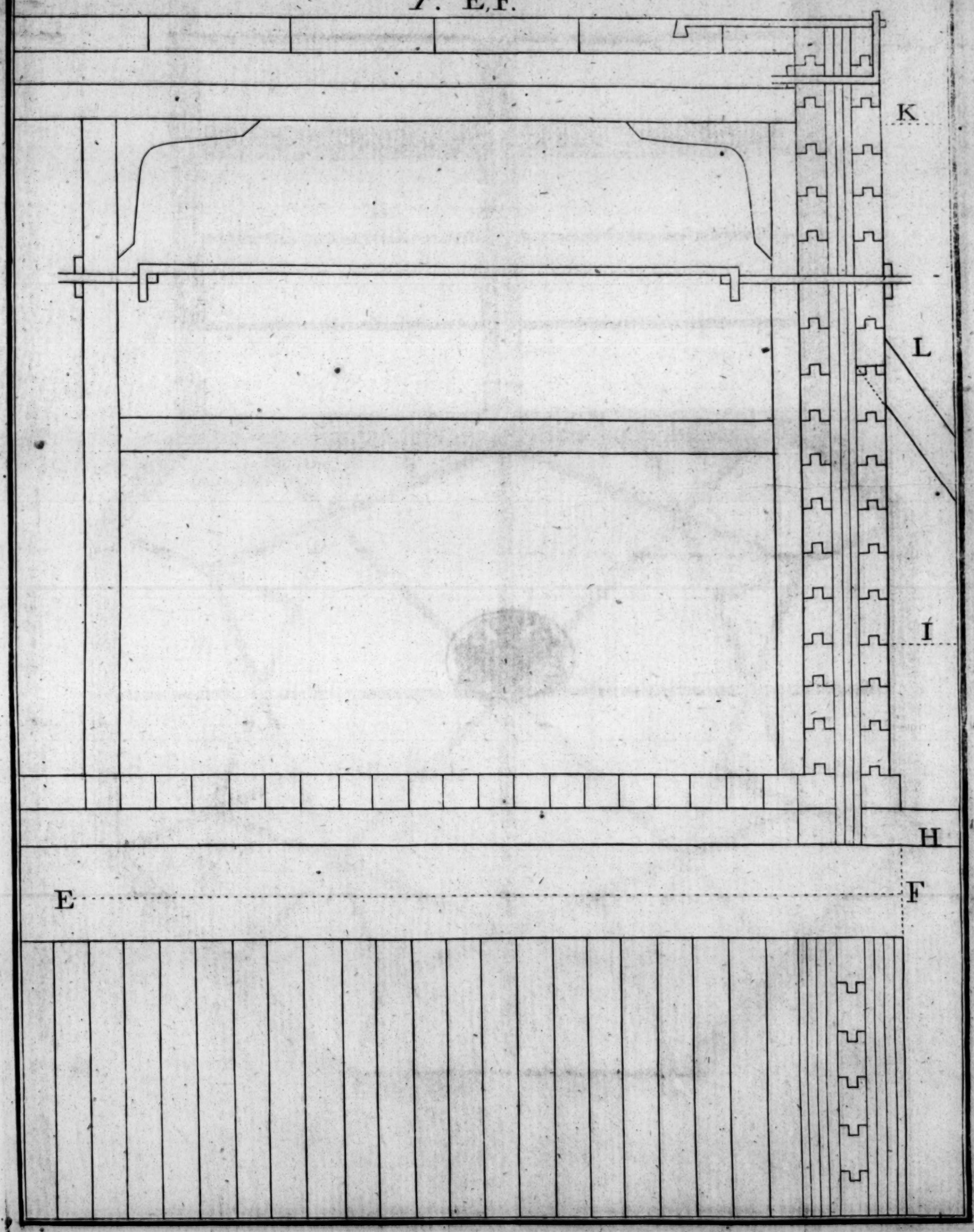
during

Pl. 52.

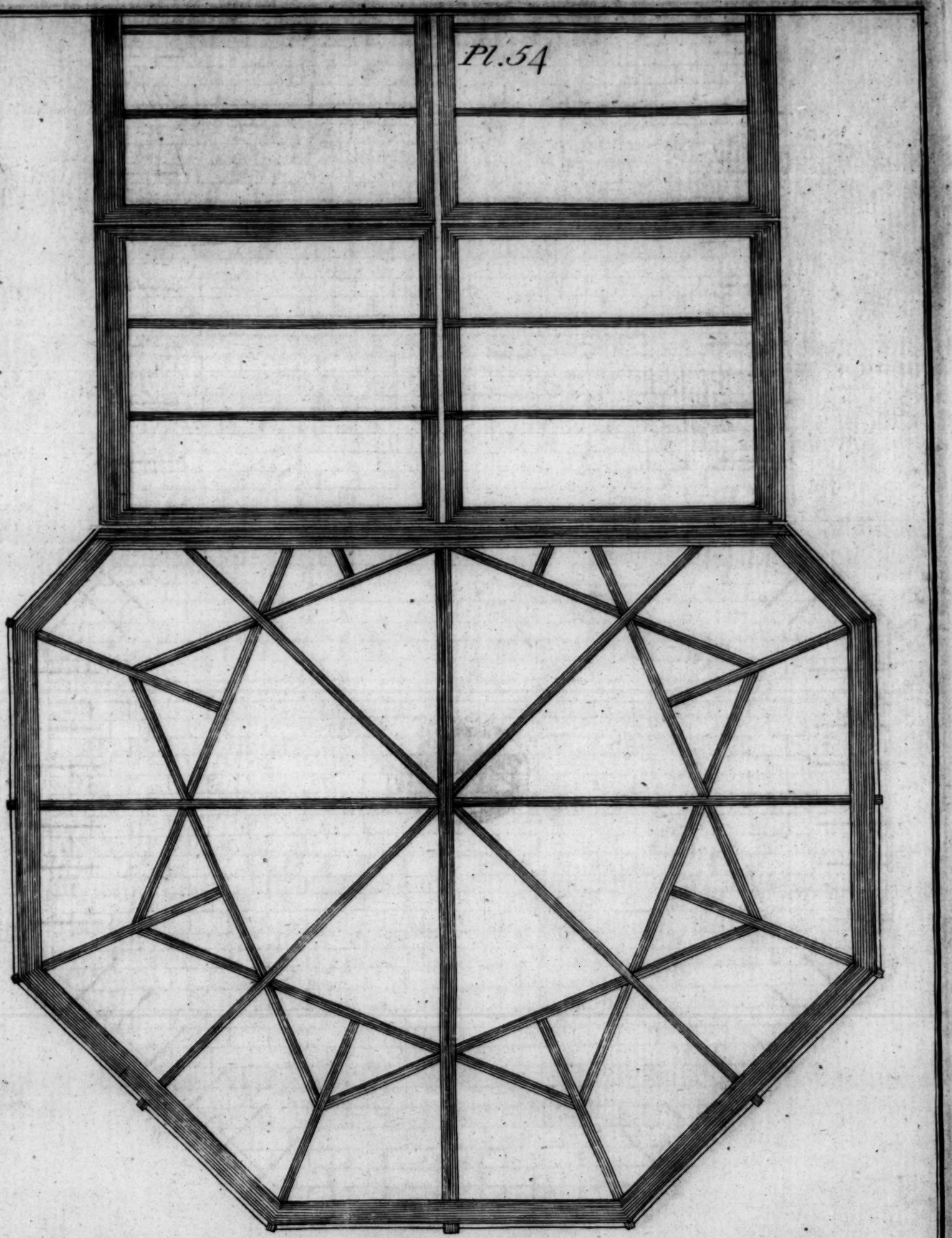


Pl. 53.

F. E,F.

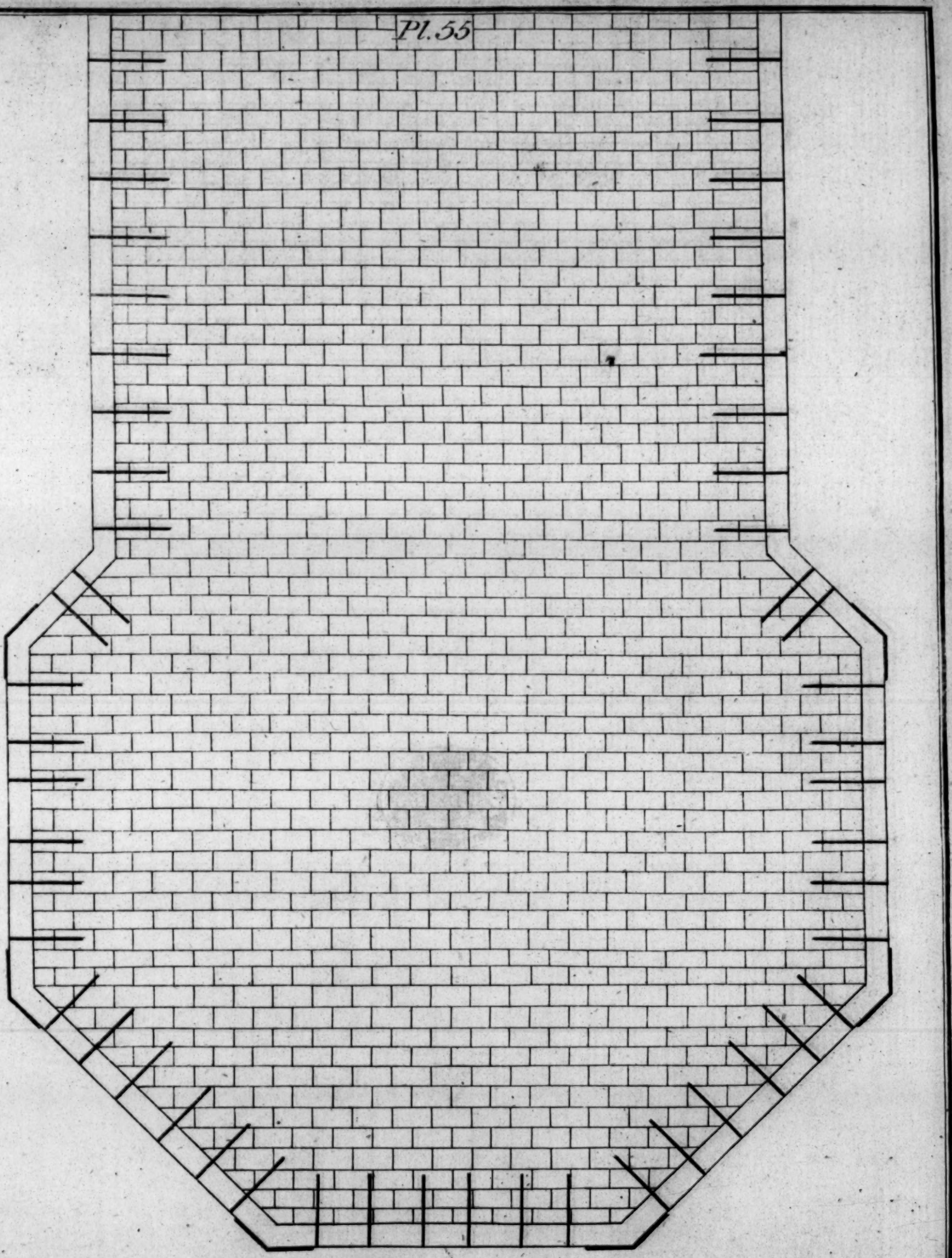


Pl. 54



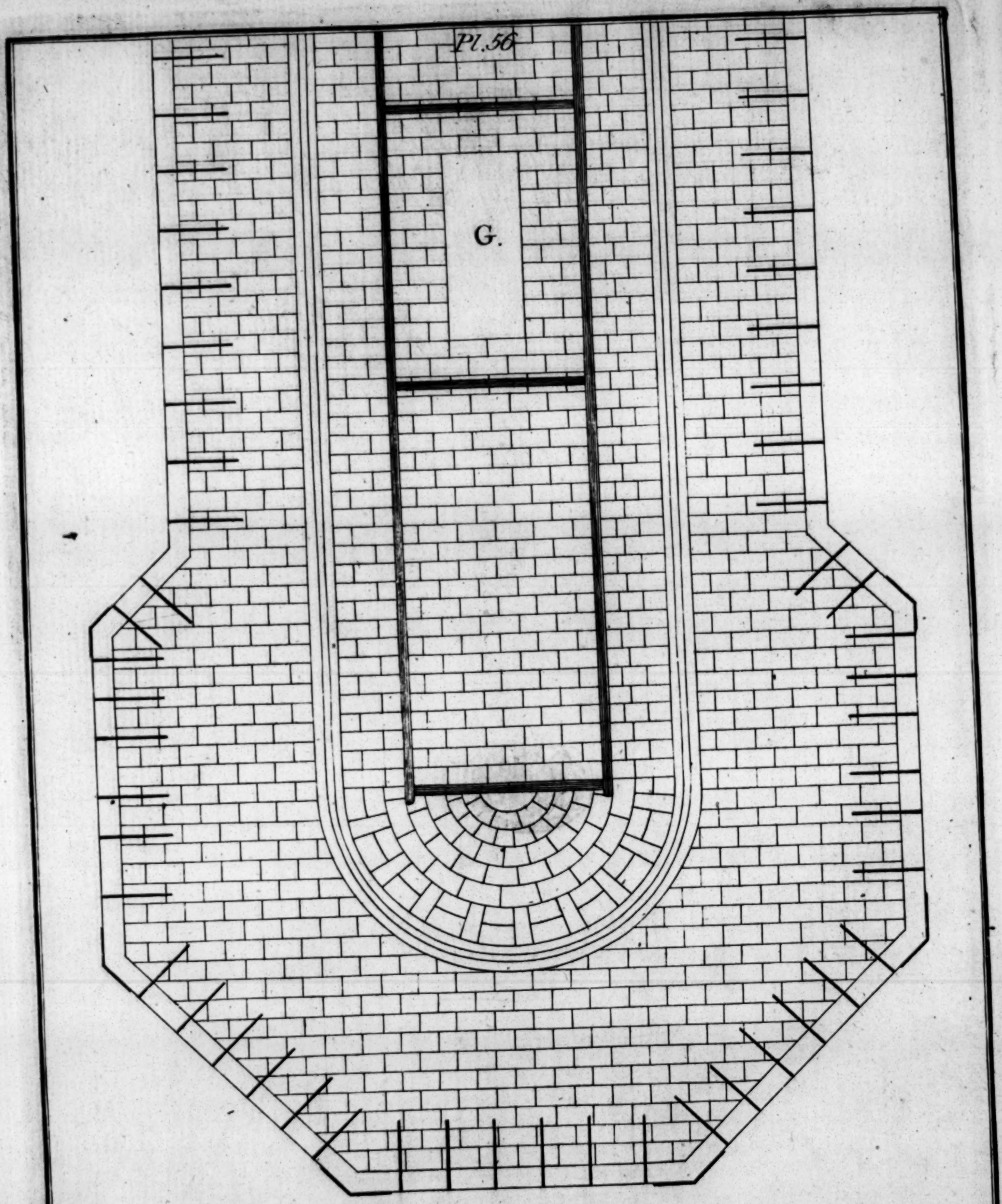


Pl. 55





Pl. 56



during Pleaſure. Obſerving alſo, that after the ſame Methods of Conſtruction, you may augment or diminiſh the Size, Shape or Strength of other Coffers, proportionable to any other deſign or purpoſe according as their various Circumſtances may require, or as your own Reaſon may direct.

Plate LVI. *(ſame Scale)* Repreſents the Plan of the fourth Courſe of the Pier-head, built on the Platform, with the Timbers that are to be framed together, and Chain-barred as formerly directed; and the like Timbers are to be repeated at about High-water mark: And obſerve, that the Coffer which you ſee left in the Stone-work of the Body of the Pier, G. is to be filled with ſtuffing, 'till you come to the Platform.

It may alſo be neceſſary for you to obſerve, that ſo much as you here ſee drawn of this Pier-head, is drawn as if the whole was to be wrought with Blocks of Cut-ſtone; yet, I do not by any Means recommend that as abſolutely neceſſary, for the Remainder of the Body of the Pier, except you have ſuch Stones very cheap; but by all Means, let the Headers, Stretchers and Tail-bonds, eſpecially in the Side next to the Sea, be done with ſuch Cut-ſtone as we have hitherto recommended; but the interior Work will anſwer effectually, if it be built with rough Stones carefully laid in ſwimming Beds of good Mortar and grouted.

I know there have been very eminent Gentlemen, who warmly recommended a peculiar Method of cutting the Stones for the outſide Work after this Manner, *viz.* To double Dovetail all the Headers, and to fit the Stretchers to fall in between them, and ſo lock them into one another; but I do not adviſe you to follow that Method, becauſe it will be tedious, troubleſome and immenſely expenſive, and of little or no Advantage to the Duration of the Work, for this material Reaſon: *i. e.* The Wind, and the flux and reflux of the Tide, do operate and principally exert their Power on the Foundation of the Pier and Pier-head, and not on the Body of it, eſpecially, if it is built in ſhallow Water. On which I ſhall give you a full Demonſtration in the next Section; nor do I think it abſolutely neceſſary for you to finiſh the outſide of the Work neither, in plain Aſhlers or in ruſtic Work, except you

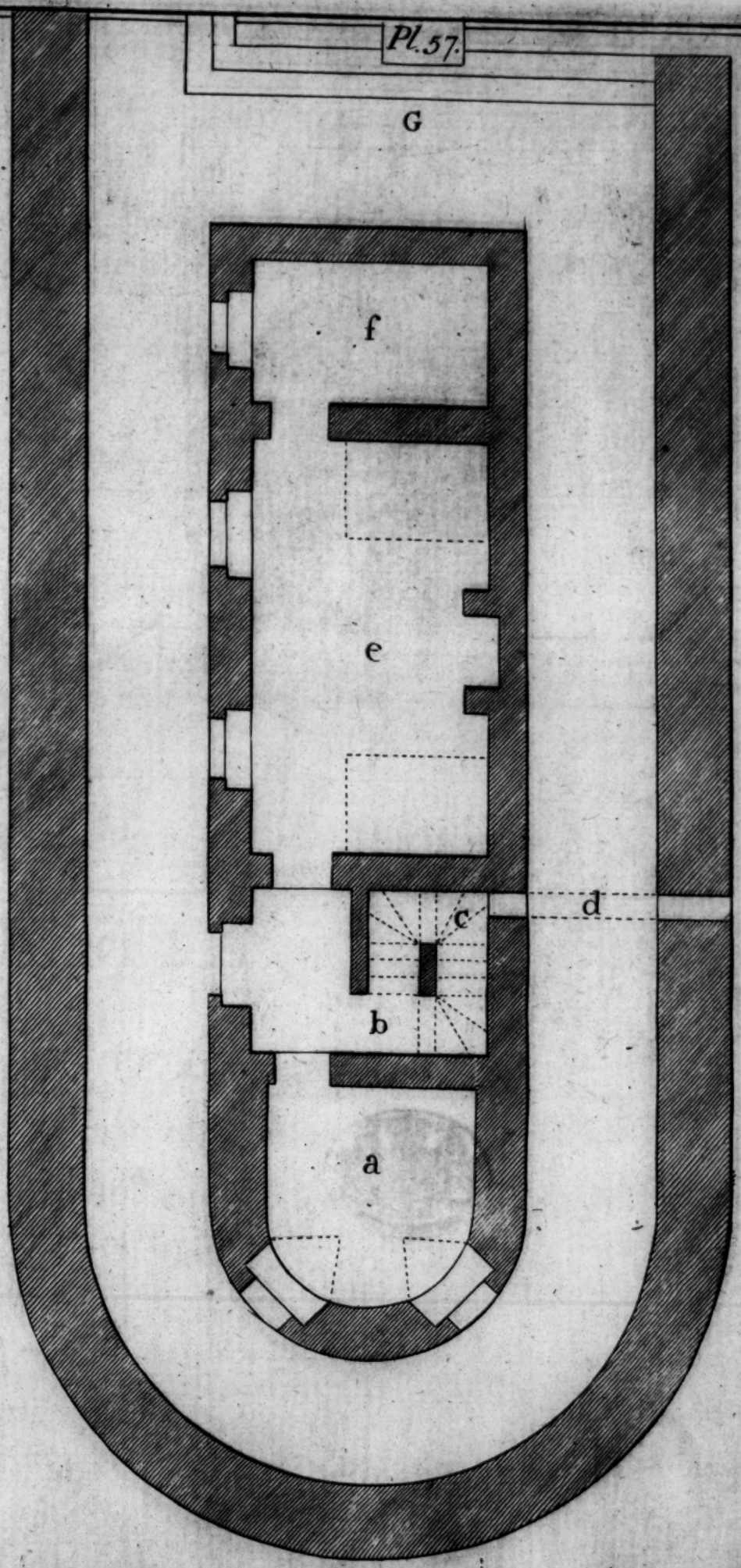
you do it for the Neatneſs of it: It may very well ſuffice, to cut the Stones ſquare in the uſual Way in Foot Courſes, and in every Courſe to make a two Inch ſet off, which with the help of the battering Plumb, will preſerve the diminiſhing of the Pier, and keep it out of winding, and though it will look a little rough to the Eye, yet it will be very effectual.

Plate LVII. (*Scale* 8 *Feet to* 1 *Inch*) Furniſhes you with a Plan of the Superſtructure of the Pier-head, ſurrounded with the parapet Wall, on the level of the third Step above the naked Body of the Pier, (which was repreſented in Plate XLVIII. Fig. 2.) Wherein note, a. Store-room. b. Stair-caſe. c. A neceſſary under the ſame. d. Sewer to be carried out under the Cut-ſtone Floor. e. Bed-chamber for the Lamp-lighter, &c. f. For his Proviſion, Coals, &c. G. The three Steps before-mentioned, the firſt of which terminates the Parapet on the Rear of the Pier.

Plate LVIII. (*Scale* 8 *Feet to* 1 *Inch.*) Fig. 1. Plan of the Stairs, Oil-cloſet and the Balcony. Fig. 2. Section of the Hall and Oil-cloſet. Fig. 3. Section of the Store-room, and half of the Door into the Balcony, the Parapet being omitted.

Plate LIX. Fig. 1 and 2. (*Scale* 4 *Feet to* 1 *Inch.*) Exhibits the Plan and Elevation of the Balcony illuminated. Fig. 3. (*Scale* 1 *Foot to* 1 *Inch.*) Is the Section of one of the Globes, which muſt be made of very thick white Glaſs; and though I do not take upon me to determine, whether Semi-globes, or common ſquare Lamps, will prove moſt commodious for your particular Purpoſe, yet I will venture to ſay, that any of them will be preferable to Coal-fires, for many ſubſtantial Reaſons, that will quickly occur on a little Conſideration; but as I have mentioned Semi-globes, I ſhall give you my Opinion of them, and whence I conceived my Notion of one ſort of them. For ſome particular Uſes I had different ſets of Moulds made of caſt Braſs, ſet in Frames of Iron; and at a Glaſs-Houſe in *Southwark*, I had them filled with the hot Metal; and they took the form, and anſwered my Purpoſe effectually. Hence I conclude, that you may eaſily get concave and convex Moulds made, that will admit of the Metal to be three Inches thick at the leaſt in the Semi-globe; and the convex Mould is to be preſſed down

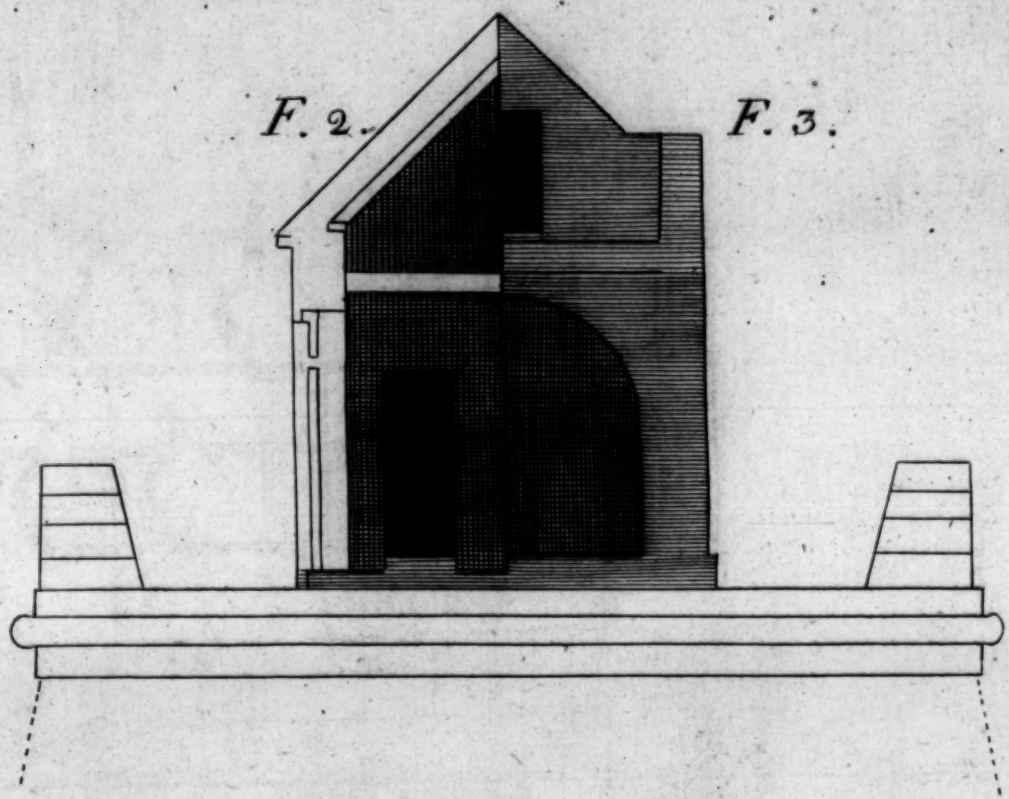
Pl. 57.





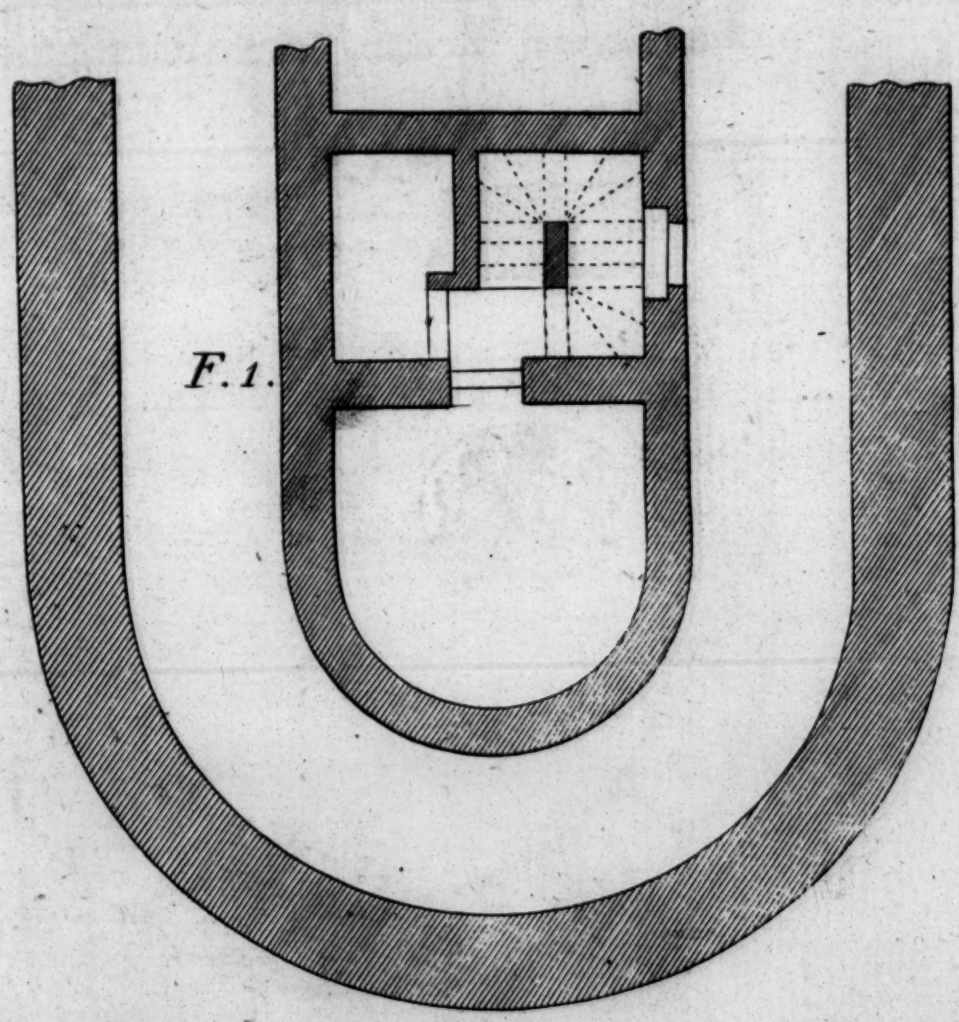
Pl. 58.

F. 2.



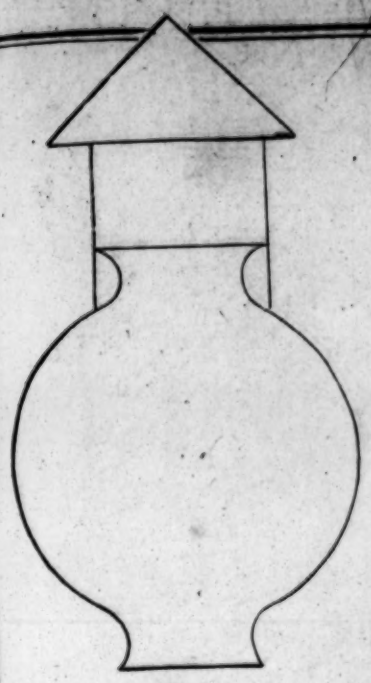
F. 3.

F. 1.



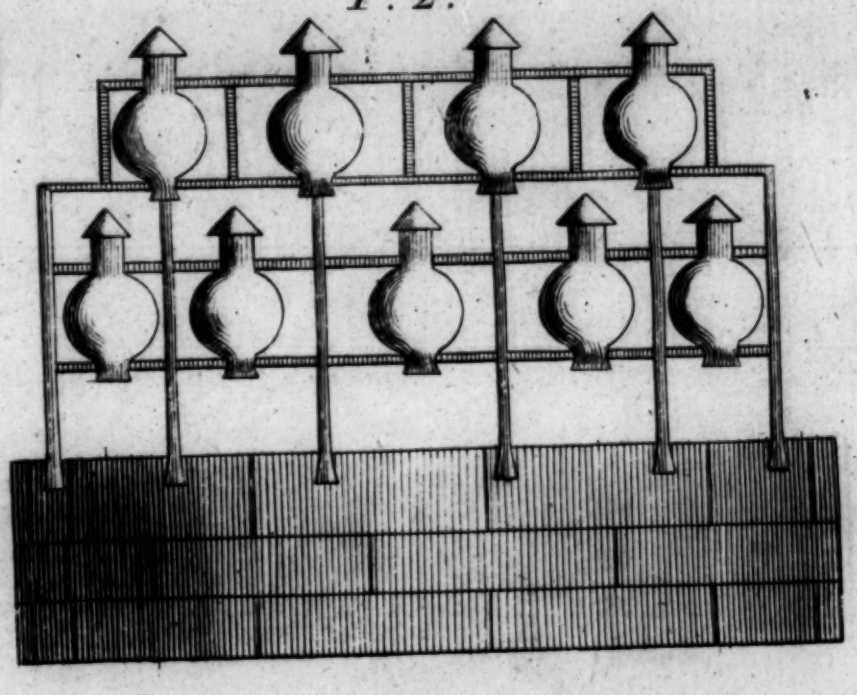


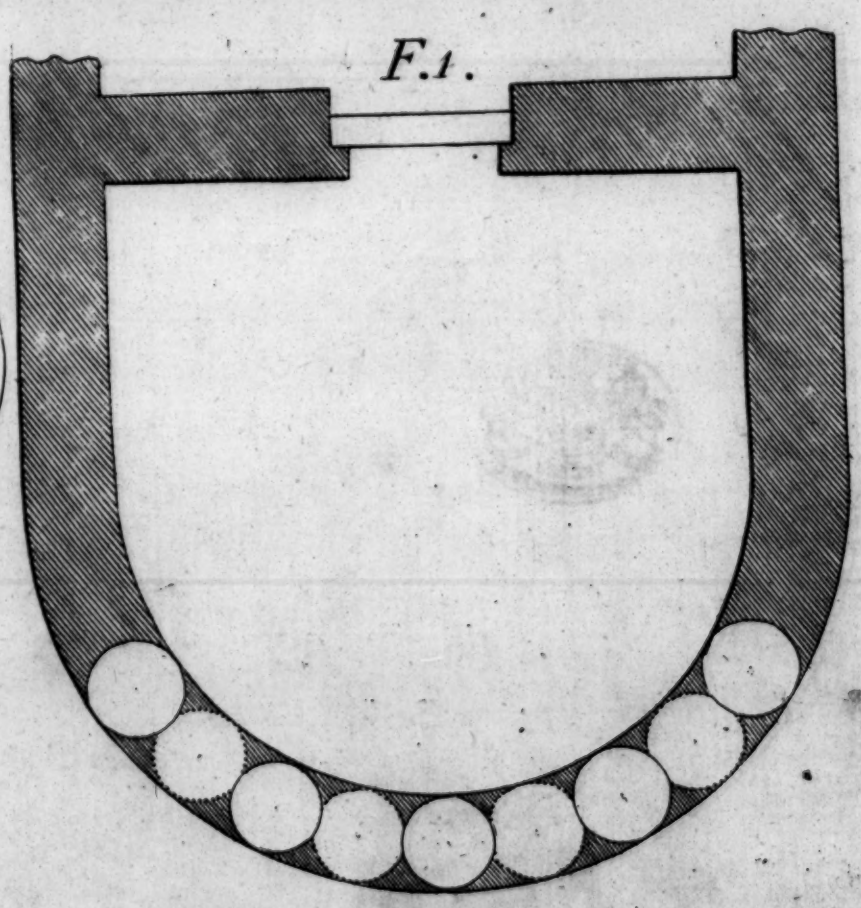
Pl. 59.



F. 3.

F. 2.

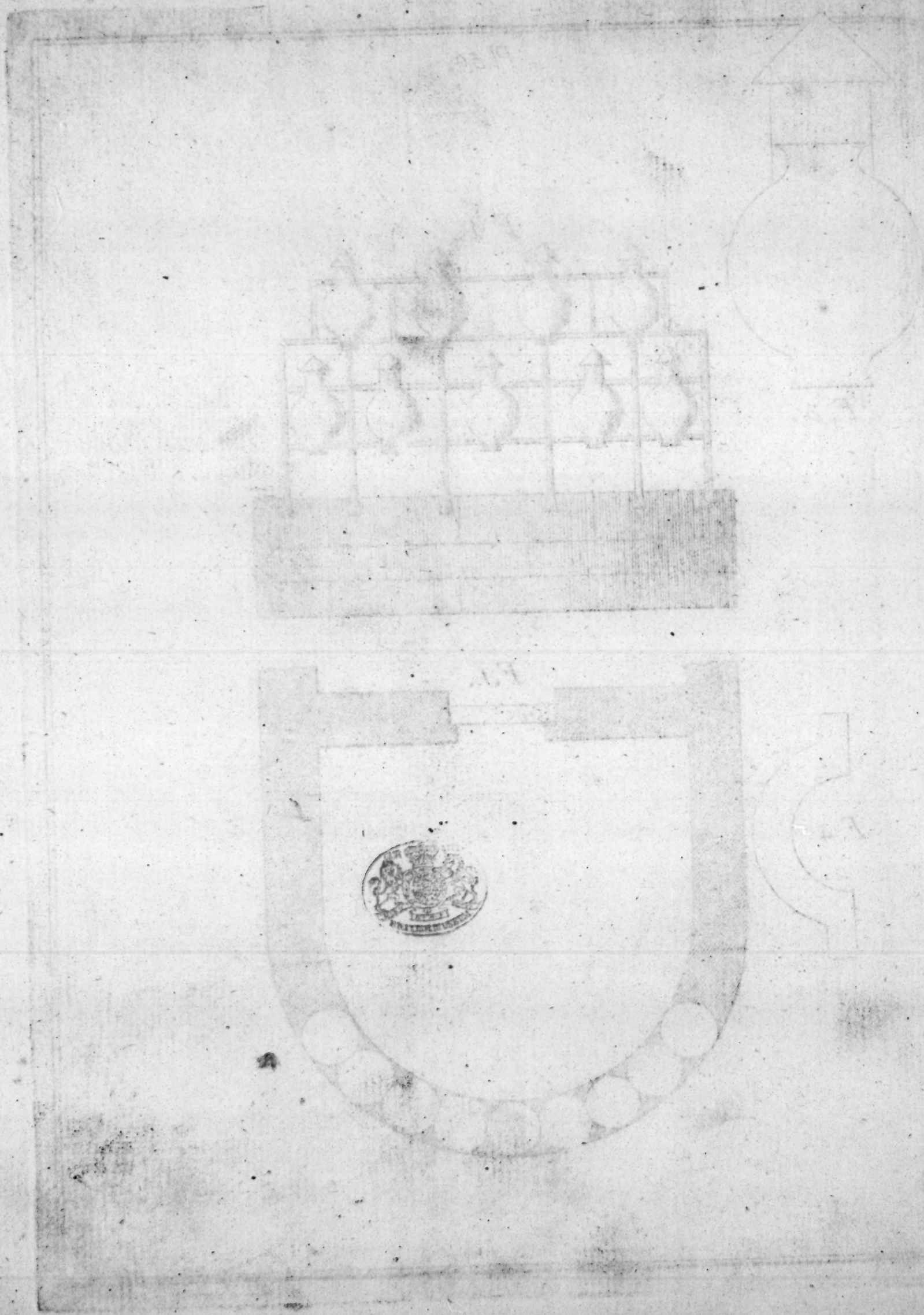




F. 1.



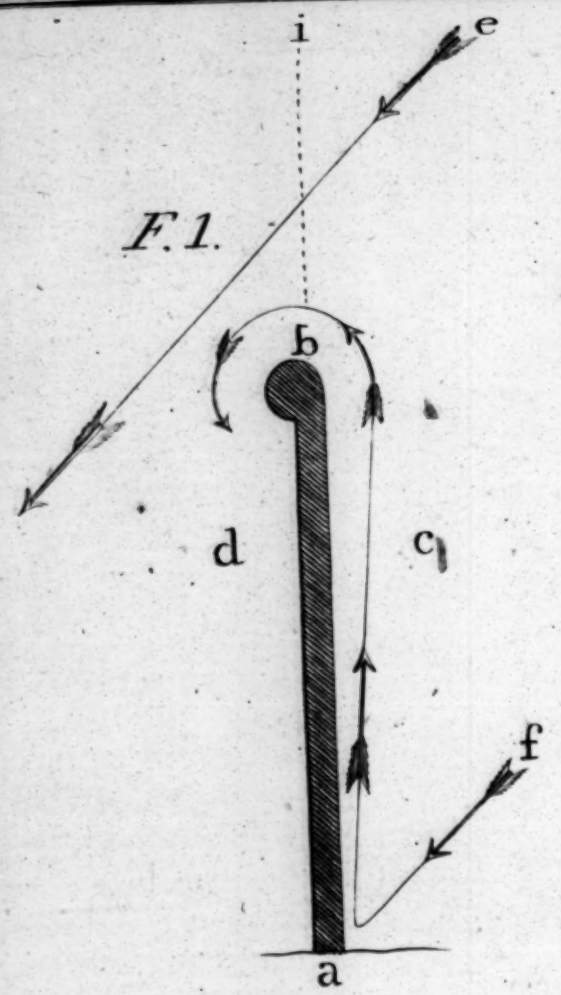
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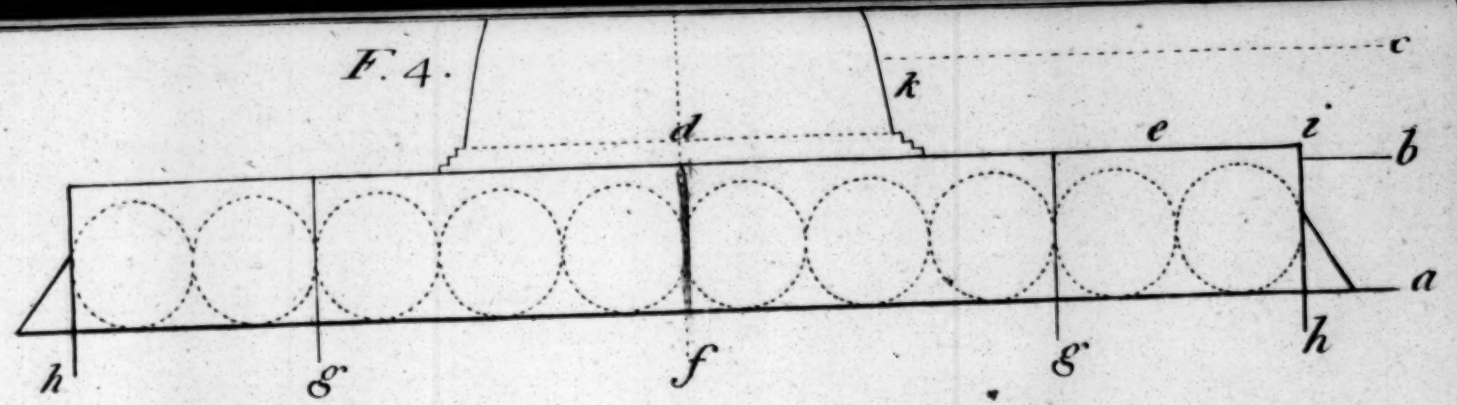


Pl. 60.

F. 1.

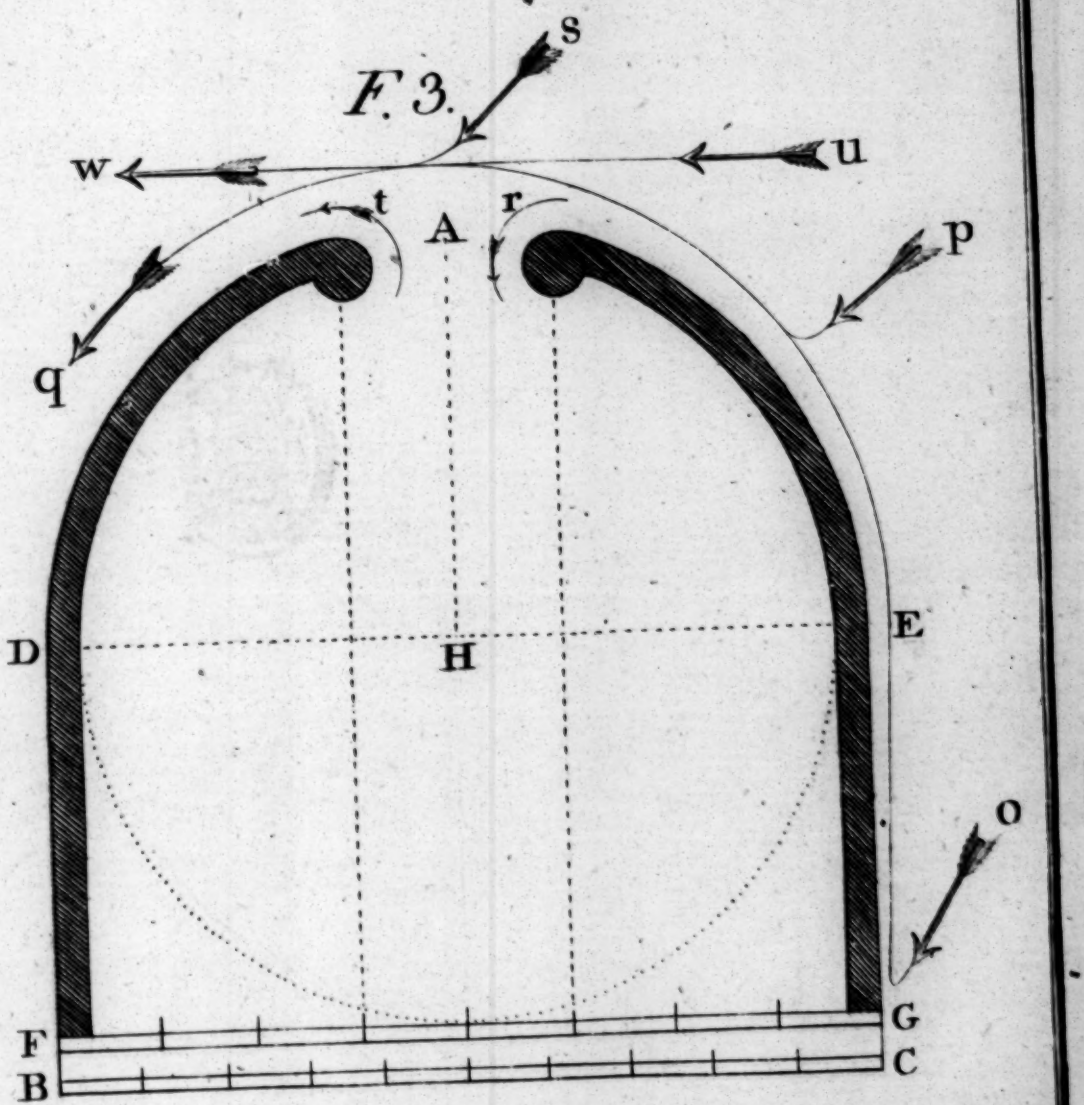


F. 4.

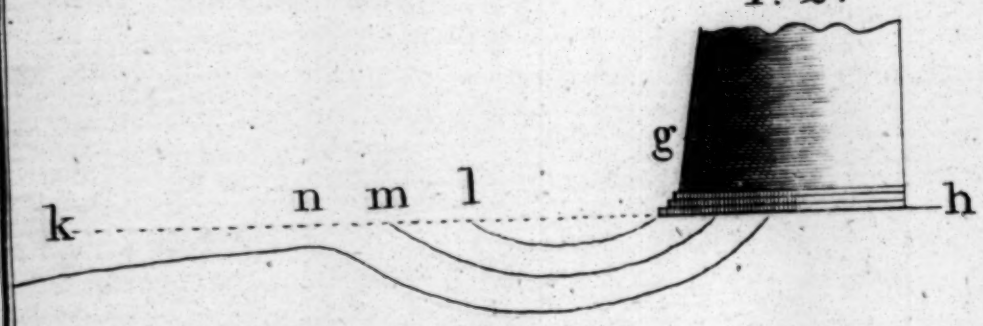




F. 3.



F. 2.



down with a Leaver into it: See Fig. 4. (*Scale* 1 *Foot to* 1 *Inch.*) Shews you the Section of this Semi-globe; and they may all be ſet in Iron Frames, leaving what room you pleaſe for your Lamp to ſtand in behind them; which I think may be very ſmall, for even the light of a ſmall Wax-candle placed in the Center of it, cannot fail of producing, to all appearance, a very luminous Ball of Fire, whoſe powerful Rays muſt needs be very conſpicuous, eſpecially if the Glaſs is clear and well poliſhed. And what then muſt the whole Illumination be with nine ſuch Semi-globes, extending near 12 Feet and 5 Feet high, all as if it were one Body of Fire, that will require very little Care or Expence to ſupport it, nor the leaſt danger of its diſappearing through neglect, and thus you may, if you pleaſe, illuminate both your Light-houſe and this Pier-head, and make other uſeful Improvements on theſe few Hints. Let us now conſider the Operations of Winds and Tides.

SECT. III.

Obſervations on the ſeparate Operations and united Powers of Winds and Tides, acting upon the Heads of ſtrait and curved Piers; built in the uſual Way at or near Low-water mark.

I HOPE we have fully conſidered and determined on the Power of the Wind and Tide in general: Let us now in a more particular Manner, obſerve their Operations upon the Head of a Pier, that is run out from the Shore in a direct Line, and built on a Bed of fine Sand at Low-water mark as uſual. See Plate LX.

In Plate LX. Fig. 1. Note, that a. Is the ſpringing of the Pier from the Shore. b. Repreſents a double Pier-head, which you may obſerve is much ſtronger than the former. c. The open Sea. d. The Harbour. e. The Current of the Flood-tide running by b. into d. And f. the Current running along the Shore to a. The Drifts of all theſe Currents are repreſented by Darts; by which you may obſerve, that the Current f. finding itſelf oppoſed by the Pier, which directs and guides it to b. in order to ſupply d. and during its Progreſs, it is preſſed forward by that which comes in

the

the like Manner behind it; and alſo meeting with freſh ſupplies from the intermediate Currents, it thereby increaſes its Power, and quickens its Velocity, in proportion to the Length it runs, till it meets with the Current e. on which a violent Conteſt enſues, each ſtriving for Superiority; but e. being much more powerful, ſoon obliges f. to yield, and preſſes it ſeverely againſt b. where they unite, and if ſuch a Pier was built at the Mouth of a large Tide-river, and the Tide flows up for many Miles into the Country, the further it is to run the greater Quantities of Water wheels round it, and conſequently, the greater will the Velocity be at the Pier-head, where it ſaps and preys on the Bed of Sand on which it is founded; and at the ſame Time the Water carries every Thing with it, that its Power is able to conquer. The alarming Effects of this may eaſily be diſcovered by Fig. 2.

In this Fig. 2. g. repreſents the extreme Part of a Pier-head, built upon the Sand at h. which is Low-water mark. The fatal Effects of the Current before-mentioned may be perceived by the Curve-line l. which repreſents a great Cavity, worn away and carried off by the two Currents e. and f. from about the Extremities of b. In order to prevent this, and preſerve the Pier-head, it has with ſome been cuſtomary in the like Caſes, to throw down large Stones round it, ſuppoſing they would preſerve it; but let us in the next Place, conſider the powerful Effects of the Wind and Tide acting in Conjunction on the Stones and Pier-head, g.

We need not enlarge on the uſual Swell of the Sea; but let us briefly reflect on the Power of an enraged Sea, agitated by a violent Storm; and ſuppoſe a Wave advancing from f. toward a. Fig. 1. where the Pier gives it a powerful Repulſe, and directs its Courſe to b. and ſo advancing along the Pier, a ſecond Wave in like Manner puſhes forward the firſt, and the third the ſecond, *&c.* And as before the Power increaſes progreſſively, in proportion to the Length of the Pier; ſo that by the Time the Current, which the Impetuoſity of theſe Waves will promote, arrives at b. if in Time of Flood, it will there join with an increaſe the Power of the Current, e. and after all, it may be very probable, that other Waves may prove much more injurious to b. even than theſe. Let us, therefore,

ſuppoſe

ſuppoſe the Wind blowing in a direct Line, as from i. to b. in Fig. 1. or from k. to g. in Fig. 2. and that a huge Wave advancing from k. to g. where the foaming Surge daſhing againſt the Pier g. breaks by that powerful Obſtruction, and then the Remains of it furiouſly recoils, as it were to recruit itſelf, and is joined with the next Wave, and makes another Attack upon g. then recoils again, and ſo on alternately.

Now pleaſe to obſerve, that theſe large Stones have (as I told you before) large Interſtices or Vacancies between and among them; and the larger the Stones are, the larger are theſe Vacancies, and, like a French-Drain, will freely admit the Water to paſs and repaſs. Conſider then, when the Wave makes the Attack, how powerfully it forces its Way through every one of the Vacancies; and, in the Repulſe, think what a moſt powerful Suction that Repulſe will create, and how it will agitate the ſubterraneous Water backward and forward, by the quick Motions of theſe Waves; and you know that the main Driſt and Operations of the Water naturally gravitate to the Bottom, and thereby break and rake it up inceſſantly. Now recollect the tumultuous Velocity of the Currents, f. and e. operating (if in Time of Flood) at the ſame Inſtant, and together with theſe Waves, hurrying all the looſe Sand and diſturbed Matters they are able to command along with them, until they have encreaſed that Curve-line, l. Then there will certainly be more of theſe large Stones thrown in; but the Wind and Current operating as before, they will ſoon ſink that Bed of Sand to the Curve-line, m. which by this Time will begin to ſap the Foundation of g. but that cannot be readily perceived, yet by a few Notes taken from the Sounding-board, it may eaſily be diſcovered, by obſerving the Line m. by Degrees ſinking down to the Line n. which will ſtill continue to advance further and further under g. 'till at Length it will totally deſtroy and demoliſh it, unleſs it ſoon meets with a Rock or ſome hard Ground; and if a ſingle curved Pier ſhould happen thus to be erected, the Operations of the Tide and Wind, may perhaps, act nearly after the ſame Manner as juſt now deſcribed; ſo that I need not repeat them. Hence it is alſo evident, that the locking of

Headers and Stretchers together, no, nor all the Chain-bars, Cramps or Ties you can make uſe of in ſuch a Pier-head, cannot preſerve it after any conſiderable Part of the Bed whereon it ſtands is ſapped and carried away from under it; which is a Truth ſo ſelf evident, that I need not enlarge on it. Therefore, I recommend it to you to remember this, and to examine your Ground well before you attempt to lay a Foundation on it, eſpecially at or near Low-water mark; but let us obſerve the Operations of Wind and Tide, on a Harbour incloſed with two Piers. See Fig. 3.

This Fig. 3. Exhibits the Plan of an Harbour incloſed with two Piers; and let us ſuppoſe, the Tide flowing from the South along the Shore, as from o. to G. and on approaching the Pier, is thereby repulſed and conducted round to q. and w. and in its Courſe, the ſmall Dart at r. inſinuates, that only a ſmall Quantity of the Tide comes into the Harbour, juſt ſo much as is barely ſufficient to keep the Water therein on a level with the ambient Water. The ſmall Dart, t. ſhews the Current of the Ebb-tide, and if the Current, p. had Liberty to exert its Power, it would be repulſed by an Arch that could not yield to its greateſt Forces; but there you ſee it joins with o. and continues its Courſe to q. and w. and the Current s. which ſeems to run directly to the Pier-head at t. is there alſo diverted and conducted to w. and q. but if we ſuppoſe the Flood tide coming from South Weſt, as from u. it will then paſs gently by the Heads of the two Piers, leaving a ſmall Quantity to keep the Water on a level as before; and the whole Current of that Tide paſſes alſo on to w. and q. without even attempting any injury to either of the Heads. Beſides theſe Advantages, a Harbour of this kind may probably afford an excellent ſhelter for ſmall Veſſels to the Northward of the Harbour, provided the direct Lines of theſe Piers extend any conſiderable Way into the Sea; whence I think it is evident, that ſuch a Harbour, if effectually executed, and in a proper Situation, may be reaſonably ſuppoſed to anſwer all the Purpoſes for which it was deſigned. I think, therefore, we may now endeavour on the Plan before us, to form and lay down principal Rules to deſign a Plan, for a Harbour of the largeſt Magnitude; but it may not be improper to take into our Obſervations,

vations, that if a Ship is making her Way from the ſoutherly Quarter, as from s. or u. to H. in a ſtrong Flood-tide and violent Storm, it may be in great Danger of running foul upon the northerly Pier-head; and this you muſt conſider, and take particular Care to guard againſt.

SECT. IV.

Concerning the Conſtruction of commodious Harbours of the largeſt Magnitude in the Sea; with Obſervations on the Operations of the Waves on the Pier-head. Fig. 4. *And alſo, a conciſe Summary of the Principles on which theſe Propoſitions are founded.*

BEFORE we can proceed in forming any Deſign of a large and commodious Harbour, incloſed with two Piers, as in Plate LX Fig. 3. I think it neceſſary to find out ſome one Dimenſion, from which we may derive a Probability of giving due Proportion to the whole: And it is evident, that here alſo we muſt be governed by the Depths of the high and low Water, which were already ſettled in Plate XLVII. Fig. 2. but the Depth of the Low-water is here particularly to be regarded, becauſe deep Low-water will invite large Ships, and large Ships muſt have a large Space to make their Tack, *&c.* See Fig. 3. which is laid down by a Scale of 100 Fathoms, or 600 Feet to 1 Inch.

In this Fig. 3. you are to obſerve, that A. muſt be looked upon as your Model, by which you are to Proportion the whole; and here it is to repreſent the Depth of the dead Low-water, which was given at 20 Feet deep; therefore from the Point A. draw your perpendicular Line, and interſect it with the Line B. C. take the Depth A. and multiply it by 100, and that will give you 2000 Feet, for the Extent of the Line B. C. which you are to divide into ten equal Parts; then take five of thoſe Parts, and ſet them down from the Point A. to H. and there draw the Line D. E. The Interſection gives you the Center, from whence deſcribe the Semi-circle D. A. E. which is the outward curve Line of both theſe Piers. Then ſet in 72 Feet, or ſix Fathoms, for the inner,

or principal Coffers of the Pier, (which appeared by p. o. v. w. in Plate XLVII. Fig. 3.) at D. and E. and thence deſcribe the inner Arch, and there will remain 1856 Feet for the Cord thereof; and upon theſe two Curve-lines at A. you are to form the Mouth of the Harbour, and Heads of the two Piers. See Fig. 4.

Fig. 4. *(Scale* 40 *Feet to* 1 *Inch)* Repreſents the principal Lines of a Section of one of thoſe Heads, taken parallel to the Line A. H. and may convey an Idea of one of thoſe Heads, ſtanding upon the Coffers. Wherein note, that *a.* is the Bottom. *b.* Low-water. *c.* High-water. *d.* Center of the Pier-head. *e.* Platform, (about 64 Feet broad). And you ſee that all theſe Coffers together extend ten Cubes of A. (i. e. $10 \times 20 = 200$ Feet). The Letter *f.* is the center Line. *g. g.* Extent of the two inner or principal Coffers of the Pier-head, which may be environed with ſlender tongued and grooved Piles, to preſerve the Lime-water. *g. h.* Breadth of the Guard-coffers, which are alſo to be environed with very ſtout Guard-piles, (the Tongues and Grooves to be put on with Spikes and ſtout Oak Pins, or made out of the Solid) to be drove down by an Engine, between the Sea-braces, as deep as poſſible, and then banked as before directed. *i.* Is the Lip of the Guard-coffer, and *k.* we ſhall ſuppoſe to be the Face or Front of the Pier-head. And having explained and conſidered all theſe Proportions, let us proceed to form the Mouth of the Harbour.

To find out the Centers of theſe Pier-heads: Divide the Line F. G. into eight equal Parts. Draw two Lines from the middlemoſt of theſe Parts, till they interſect the inner Arch-Line, which gives you the Centers required; which is equal in Diſtance to 500 Feet from Center to Center, or the fourth Part of F. G. (i. e. $A. = 20 \times 25 = 500 \times 4 = 2000$.) and each of theſe Centers are the ſame as *f.* in Fig. 4. Whence the Whole of the Coffers projects 100 Feet, or five Cubes of A. from *f.* to *b.* on each Hand, leaving fifteen Times A. or 300 Feet, for the Mouth of the Harbour between the Coffers. Thus you have ſeen that the Depths of the Water laid down in Fig. 2. Plate XLVII. has principally governed the whole of theſe Deſigns. The

Height

Height of the ſpring Tide, a. b. directed you to Proportion the Pier, and the Depth of the dead Low-water, a. A. enabled you to proportion the Extent of this Harbour; each of which, or any Part thereof, you may by the ſame Rules, either augment or diminiſh, according as various Circumſtances may require.

Having obſerved the Operations, and conſidered the united Powers of Wind and Tide acting upon the Heads of ſtrait and curved Piers; let us, in the next Place conſider, that if a Ship is making her Way from s. or u. to H. in a ſtrong Flood and violent Storm, ſhe may perhaps, be in danger of running foul upon the oppoſite Pier-head.

To this Intent, let us ſeriouſly reflect on what has paſſed, and attentively conſider, whether ſuch a Work as this would be able to ſuſtain ſuch a violent Shock, as might happen from a large Veſſel being precipitately forced againſt it.

I preſume it is quite out of our Province, to determine preciſely, the Power of any ſuch Weight ſtriking againſt either a direct or inclined Plain, ſuch as I apprehend either the one or other of the Sides of theſe octagonal Coffers may fitly be compared to; but let us much rather endeavour in a plain clear Manner to conſider, whether we may reaſonably hope that this Work (ſuppoſing it to be properly executed) would be able to withſtand ſuch a powerful ſhock or not: And on this enquiry, we muſt firſt obſerve, (ſee Plate LX. Fig. 4.) that the Head of this Pier is ſo remote, that even the feeble point of a Bowſprit, would perhaps, ſcarcely reach to touch it, and therefore, the Coffers alone muſt ſuſtain the ſhock. Now it is neceſſary alſo to obſerve, that theſe Coffers, taken together, from h. to h. be 200 Feet Diameter, and 23 Feet high, as hitherto determined; and here recollect the ſubſtantial Conſtruction of the Coffers formerly laid down, how firmly they are braced, and made perfectly ſolid and compact with ſubſtantial and durable Materials; and that the Lip of the outward Hull, may perhaps, ſeem to be the feebleſt and moſt expoſed Part of it. Now, in order to reconſider this, turn back and look at Plate LV. You know how that was directed to be done, and this is to be done after the ſame Manner; and think, how firmly and ſubſtantially

ſtantially that Cut-ſtone Platform will brace and ſtrengthen the Lip of that Coffer. Conſult your own Reaſon, or that of any other judicious Perſon, on this plain Queſtion, *viz.* Could any Ship by running ſoul on the Lip of thoſe Coffers in any Direction, compreſs the Stones of this Platform any cloſer than they are here ſuppoſed to be laid? and if not; How can they yield or give Way to it? But taking it in another light: There is no doubt, but that even ſome Mariners will apprehend, that ſuch a Coffer would be an inſignificant Obſtacle to a firſt rate Man of War under full Sail; but it may be alſo neceſſary for them to conſider, that this Coffer (excluſive of the immenſe Weight of the Pier-head, and the lofty Beacon, or Light-houſe, that is to ſtand upon it) would weigh upwards of fifty thouſand Tons, which we have found to be equal in Weight, to a ſolid Rock of *Portland* Stone of thirty-four Fathoms in Diameter, and near four Fathoms in Height; whence, perhaps, he or they may be able to form a clearer Judgment on the Effects of ſuch a Rock, lying directly in the Road of ſuch a Ship under full Sail; and on the Deciſion, you are to anſwer the Queſtion propoſed. We ſhall in the next Place, make ſome conciſe Obſervations on the Operations of the Waves on the Pier-head now before us. (Fig. 4.) The Depth from *a.* to *b.* being 20 Feet.

Let us conſider a large Wave advancing from *b.* towards the ſuppoſed Pier-head, *k.* in its Way, the lower Part of it only will meet with, and be retarded by the Obſtacle, *i.* the upper Part of it, will break and diſperſe on the Cut-ſtone Platform, *e.* and being thus weakened, when the remains of it ſtrikes againſt *k.* it will make but a very feeble recoil during the Time of Low-water or young Flood. But let us ſuppoſe, a Wave advancing in a direct Line from *c.* to *k.* it will not meet any Obſtacle till it arrives at *k.* where its full Power can only ſtrike on one point, and diſperſe circularly, which will partly diminiſh its Power in recoiling, and the remaining Part of its recoiling Force, not meeting with any Obſtacle, will be quite ſwallowed up in that Depth of Water. And alſo obſervé, that Waves advancing through the intermediate Space, between *b.* and *c.* both their attack and recoil will operate entirely

entirely on *e.* which will be, as if it were, a Stage of Cut-ſtone of 64 Feet broad, prepared for them to act on.

The Motions and Celerity of the Waves, have been fully examined by many eminent Gentlemen; ſeveral of whom have on very juſt Grounds concluded, that the Motions of the Waves, even in a high Storm on the main Ocean, does not ſenſibly agitate the Water to any conſiderable Degree of Depth, from the Surface of the Caveties thereof; ſome ſay, not exceeding one Fathom deep: And if ſo, then generally ſpeaking, the Water at *a.* will continue nearly in its natural tranquil State, and conſequently, can neither diſturb the Banking, nor ſap the Foundation. Hence it is evident, that the utmoſt united Powers of Wind and Tide, can neither injure nor moleſt theſe Coffers, which is the principal Thing required.

But before I preſume to introduce this moſt important Propoſition into Practice, I think it adviſeable to ſum up, and to lay before you in one View, the Principles upon which I have founded theſe 12 Propoſitions, which I ſhall reduce to the following ſix conciſe Articles, in order to your forming a clear Conception of their Nature and Utility.

I. That ſound hearty red Fir-timber, kept conſtantly in Water, will be extremely durable; and the Iron Cramps eaſily replaced if neceſſary.

II. That theſe ſmall Stones, properly mixed with clean, ſharp, ſandy Gravel, *in Water*, excluſive of Lime, and being cloſely and ſecurely confined together, will inſtantly become firm and compact, and conſequently be a ſubſtantial Foundation for any Building whatever.

III. That the Stuffing hitherto recommended, will moſt aſſuredly turn to a real Petrification; and, that each of theſe Coffers will, in reaſonable Time, contain one compact Subſtance, equal to the Strength and Durableneſs of a hard and ſolid Rock, which will be of the ſame ſhape of the clear of the Coffers in which they were moulded; and will be poſſeſſed of this remarkable Advantage, that the longer it ſtands, the harder it will grow.

IV. That

IV. That theſe Kinds of Foundations, in the weightieſt Works, may (generally ſpeaking) be effectually accompliſhed, with ſurprizing Expedition, perhaps, by an ordinary Ship's Crew, and at a trifling Expence (in Compariſon with other Methods) in any Country, throughout the greateſt Part of the Univerſe; as there are, probably, but few Countries that do not afford ſuch common Materials as are neceſſary for thoſe Purpoſes.

V. That theſe Kinds of Coffers may be proportioned to any moderate Depth of Water; and that Coffers of fifty Feet high, may, in moſt reſpects, be as readily conſtructed, and the Work as effectually executed in a freſh Water, or in a moderate Tide River, as in any other leſſer Depth, the Proportions being duly conſidered.

VI. That in any kind of Buildings that may hereby be erected in the Sea, it may alſo be obſervable, that if the Coffers were even made much ſlighter, yet, as they will be in a Manner quite beneath the Power of either Wind or Tide, they may be abundantly ſufficient to oppoſe them both, and conſequently, they can only operate on the Cut-ſtone, which they cannot injure. I hope, therefore, that I may ſafely conclude, that theſe are ſure, quick and cheap Methods for compleating ſuch Works, which are the three Things that I have endeavoured to accompliſh. With this View, therefore, and on theſe Principles, I ſhall now venture to introduce this Propoſition into practice, by laying before you, the Plan of a Harbour for the *Downs*, in *England*; which you may apply or vary, according as other particular Circumſtances may require, either in that Place or elſewhere. And obſerve, that in this enſuing Deſign, in the Place of Fig. 2. Plate XLVIII. you may (by a large Scale) draw the Section, Fig. 4. Plate LX. with a Superſtructure proportionable to it; and lay down the octagonal Plan thereof, ſo as to corroborate with the Plans of theſe curved Piers in Fig. 3. and alſo in Plate LXI. The Heads of which, I have been obliged, by the ſmallneſs of my Scale, to draw circular, and to omit all the Guard-Coffers; but I hope, all the other Parts and Proportions of theſe Methods, are ſo clear and diſtinctly laid down in them, and in the foregoing Plates, that I need not enlarge any further on them;

and

and obſerve alſo, that the Height of the ſoutherly Pier in this following Deſign, muſt perhaps, be of the ſame Dimenſions as formerly laid down, Plate XLVIII. Fig. 1. But the Height of the North Pier, is entirely left to your own Diſcretion, with many other Circumſtances which after ſtrictly examining the Coaſt, you muſt determine on, as the Reſult of deliberate Conſideration.

SECT. V.

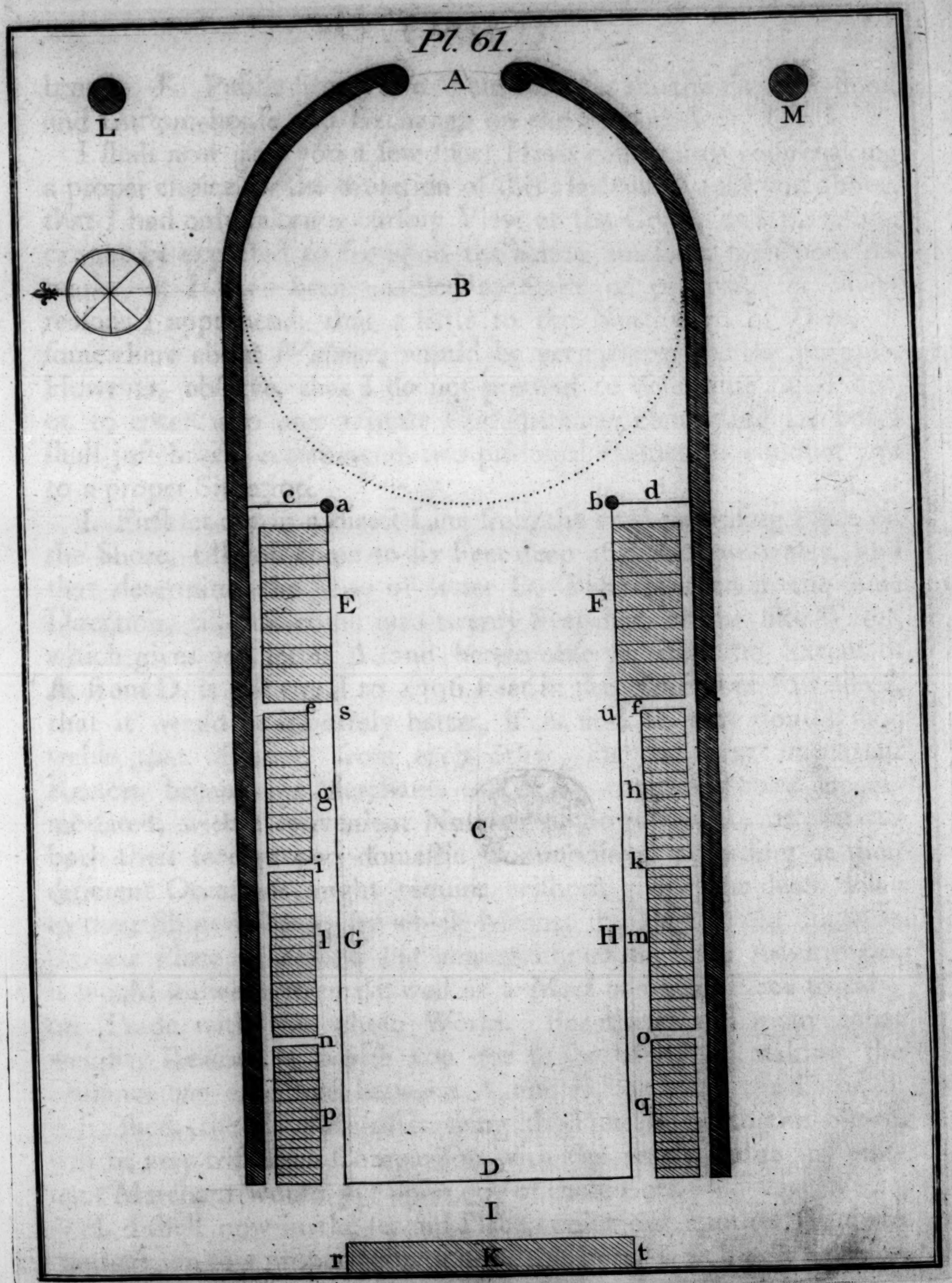
Concerning the Conſtruction of a Harbour for the Downs, *projecting to* 20 *Feet Low-water, the higheſt ſpring Tides ſuppoſed not to exceed* 20 *Feet more.*

I HAVE told you that in *June* 1752, I went to *Ramſgate*, to conſult Mr. *Ettridge* and Mr. *Preſton*, who were pleaſed to favour me with a Copy of the Plan of their Harbour. During my Stay there with them, and the Captain that brought them the *Portland* Stone, great Part of our Converſation turned on different Opinions, concerning a Harbour for the *Downs*; and as I then had an Opportunity of hearing many pertinent Remarks on the Subject, to ſatisfy my Curioſity, I took a curſory View of the Shore thence to *Dover*; and I afterwards collected ſeveral other Plans, Charts and other Remarks; and on my return Home, employed one of my Clerks to copy them, and reduce the whole into a conciſe little Book, which now lies before me, and which I have many Times ſtudied with the greateſt Aſſiduity, in hopes of accompliſhing what I moſt earneſtly deſired: And at Length, I compleated what I am alſo now about to lay before you, as the ultimate End of theſe Propoſitions; but obſerve, that all the Materials which I collected, were not by any Means ſufficient to determine me, eſpecially as to the propereſt Situation for it, becauſe I had not any Borings, or correct Soundings of high and low Water; I muſt therefore, leave theſe Matters at your Door, but ſhall give you a few neceſſary Hints concerning the Situation in the Sequel.

PLATE LXI. *(Scale 100 Fathoms or 600 Feet to 1 Inch.)*

This Plate exhibits the Plan of the Harbour, which I have deſigned according to the general Rules of Proportion, laid down in Plate LX. Fig. 3 and 4. And herein note, that A. is the Mouth in tweenty Feet deep of dead Low-water. B. The Baſon for the largeſt Ships, extending 1856 Feet, or about one third of an *Engliſh* Mile, in the clear of the principal Coffers as before, which in this, or the like Caſes, you may diſpoſe of after the following Manner: Out of this 1856 Feet, take the odd 56 Feet, and divide them into two equal Parts, and give one of thoſe Parts to enlarge the Thoroughfare at the Rear of the Lots; then divide the 1800 Feet into 18 equal Parts, three of which (being 300 Feet) are to be the Depth of the Lots on each Side, and the remaining 1200 Feet are to be the Breadth of C. which is to be the Port or Haven for trading Veſſels, (which is juſt the Breadth of the River *Thames* at *Weſtminſter-bridge*). D. Is the Port-head at the Cuſtom-houſe Quay, which muſt be ſix Feet deep at the dead low Water. a. and b. Are two ſmall Beacons. c. and d. Two Quays of 328 Feet long, and 70 Feet broad each. E. and F. are twenty Lots for Docks, each Lot ſeventy Feet Front, and 300 Feet deep. Then divide the 300 Feet into three equal Parts, of which you leave two on each Side for the Depth of theſe Lots, and one on each Side for G. and H. which repreſents the two principal Quays, each of which will be 1770 Feet long, and 100 Feet broad. Wherein alſo note, that e. and f. are Thoroughfares to the Rear, and 50 Feet broad each. g. and h. Twenty-four Lots for his Majeſty's Magazines, being 50 Feet Front, and 200 Feet deep each. i. and k. Thoroughfares of 40 Feet broad. l. and m. Thirty Lots of 40 Feet Front, for public Stores and Weigh-houſes. n. and o. Thoroughfares of 30 Feet broad. p. and q. Thirty Lots for principal Merchants Companies, to ſtore their Imports and Exports, till further Orders. I. A yard, wherein you are to make the Coffers, *&c.* and afterwards it is to be the Cuſtom-houſe Quay, extending 1200 Feet long, and 300 Feet broad.

Pl. 61.





broad. K. Public Stores and Weigh-houſes on the Ground-floor, and Cuſtom-houſe and Exchange on the Second-floor, &c.

I ſhall now give you a few ſhort Hints concerning your making a proper choice for the Situation of this Harbour. I told you above, that I had only taken a curſory View of the Coaſt, and therefore, cannot be expected to fix upon the Scite; but from ſuch poor remarks, as I have been enabled to make or procure, for many reaſons I apprehend, that a little to the Northward of *Deal*, or ſomewhere about *Walmer*, would be very proper for the purpoſe. However, obſerve, that I do not pretend to determine this Point, or to enter into any minute Circumſtances concerning it; but I ſhall juſt briefly recommend two principal Guides to conduct you to a proper Situation.

I. Firſt ſet out in a direct Line from the moſt promiſing Place on the Shore, till you come to ſix Feet deep at dead Low-water, and that determines the Scite of letter D. Then proceed in the ſame Direction, till you come into twenty Feet deep of the like Water, which gives you letter A. and herein obſerve, that the Extent of A. from D. is juſt equal to 4396 Feet in the clear; but I preſume, that it would be infinitely better, if A. and D. were double nay, treble that diſtance, from each other, for this very important Reaſon, becauſe the Merchants of *London* would be better accommodated, with a convenient Number of Store-houſes, to preſerve both their foreign and domeſtic Commodities, according as their different Occaſions might require, without giving the leaſt delay to their Ships or Men; by which Means, this Port would not only prove a Place of Safety, but among numerous other Advantages, it would anſwer extremely well as a Mart or noted Place to carry on Trade with the whole World. For theſe, and many other weighty Reaſons, I adviſe you not to be afraid of making the Diſtance too extenſive between A. and D. for when the Baſon B. is finiſhed, the Expence of carrying the Piers home to the Shore, will be very trifling in Compariſon with the yearly Value any eminent Merchant would put upon one of thoſe Lots.

II. I ſhall now in the ſecond Place, point out another Guide to conduct you to a proper Situation for this Port, which you will find

to be of ſuch vaſt Conſequence, that neither Time nor coſt ought to be ſpared to find out and procure it, if poſſible; and that is a full command of pure freſh Water.

I cannot certainly ſay, whether or no the River *Stower* could be taken up, or even a Part of it, conveyed to ſome convenient Place for this Purpoſe; but I have Reaſon to believe that it may, or perhaps, ſome other Rivulet may anſwer better; but be that as it will, I do moſt earneſtly adviſe you, to procure plenty of pure freſh Water, ſufficient to keep up in the drieſt Seaſon, a ſpacious Reſervoir, contiguous to the Rear of K. or ſomewhere to the Weſtward of the Port; and from this Reſervoir to carry two Conduits, one through the Middle of each Quay-wall, as it were from r. to s. and from t. to u. they muſt be at the leaſt 4 Feet wide, and 7 Feet high in the clear, to be built with well chiſſeled Stone, in ſtaunch Ciſtern Work, as formerly directed, each of theſe Conduits muſt have a Sluice at the Reſervoir, and another near to the Extremity of each Quay as at s. and u. into which common Sucking-pumps muſt be ſet at about every Ship's Length, in Proportion to the ſeveral Depths of Water, with proper Air-pipes, *&c.* This I repeat, will be of ſuch vaſt uſe, that no Money ſhould be ſpared to procure it. I ſhall give you but one Inſtance on the whole: Suppoſe a Sloop or Tender, ſhould come to this Port in great haſte for Ammunition, or Proviſion, ſhe might ſail up to the Magazines and be inſtantly loaded; and yet, at the ſame Time, by the Labour of three or four Men, this pure freſh Water can be pumped, and by Leather-tubes conveyed, even into the Water Hogſheads in the Holds; and with all this ſhe might ſet out again, without paying any regard to the Tide, or loſing the leaſt Time imaginable by taking in her loading.

I do not in the leaſt doubt, but that there will be ſome political Objections made to this Deſign; becauſe perhaps, this Port might at ſome Times contain immenſe Value of *Britiſh* Property, and in Time of War be liable to Hoſtilities. In order to obviate that Objection, you may on theſe Principles and Methods erect two ſubſtantial Forts at L. and M. provided you find thoſe two Scites

of

of moderate Depths, by which I preſume, this Port may be ſafely protected, and the Channel effectually guarded thereby.

Plates LXII. and LXIII. furniſh you with the Scales, by which all the foregoing Draughts were minutely laid down, except Fig. 3. in Plate LX. and Plate LXI.

Thus have I, to the utmoſt of my Capacity, at Length gone through the Deſign I propoſed, and which I have ſo much at Heart; and if the Ends I had in View ſhall be anſwered, and theſe Sheets may in any wiſe conduce to the national Welfare, and the Inſtruction of young Students in Works of this Nature, I ſhall be ſo far from regretting the Labour I took in compoſing, and the Expence I have been at in publiſhing them, that I ſhall ſit down with all the Self-complacency that ariſes from a Conſciouſneſs of meaning well.

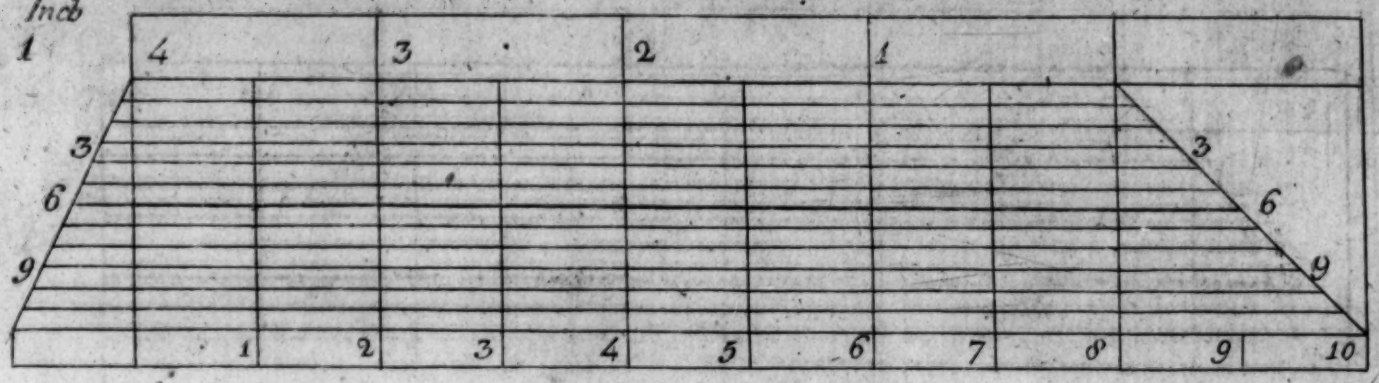
FINIS.

ERRATA.

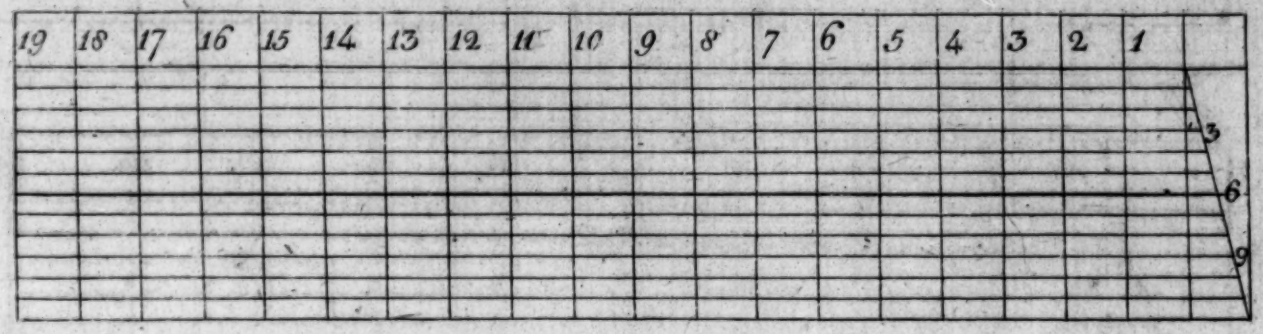
Page 76, *line* 22, *for* homely *read* home.——*Page* 100, *line* 9, *for* a. b. and c. *in Plate* 23. *read* e. f. g. and h. *in Plate* 8. *fig.* 2.——*P.* 135. *l.* 33. *for* f. e. *read* f. k.

Pl. 62.

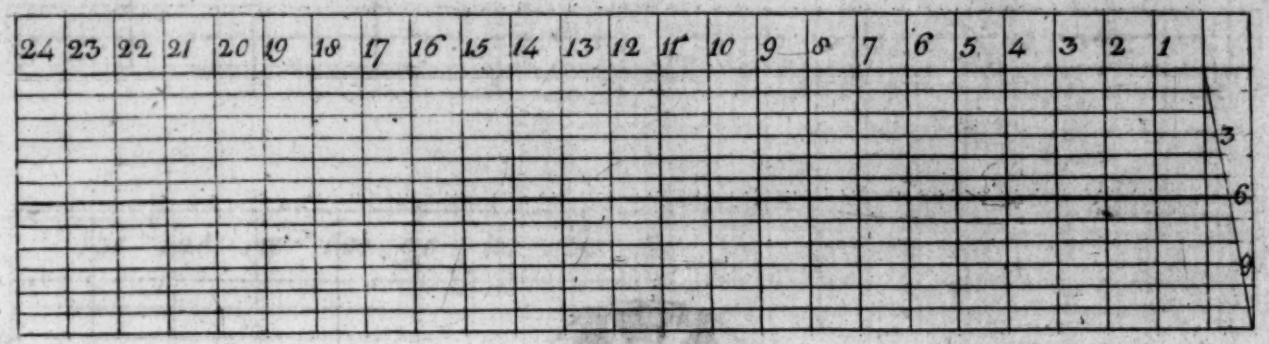
Foot Inch
1 = 1



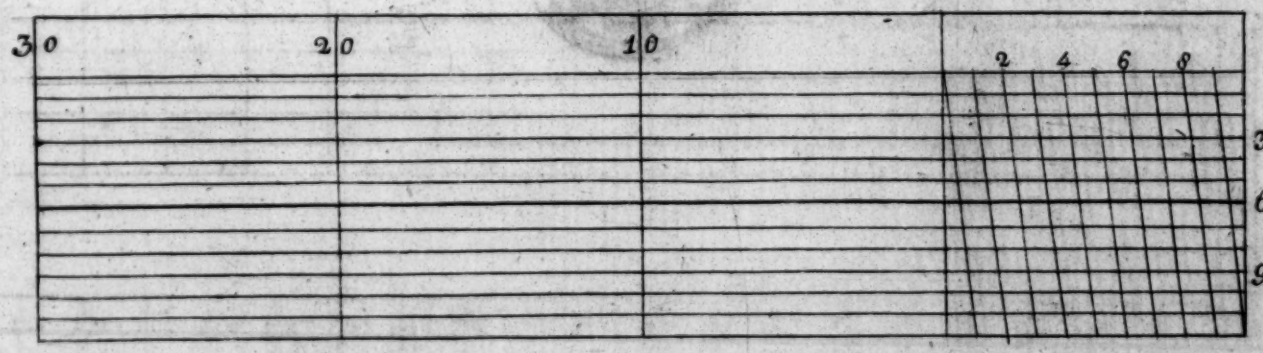
2 = 1



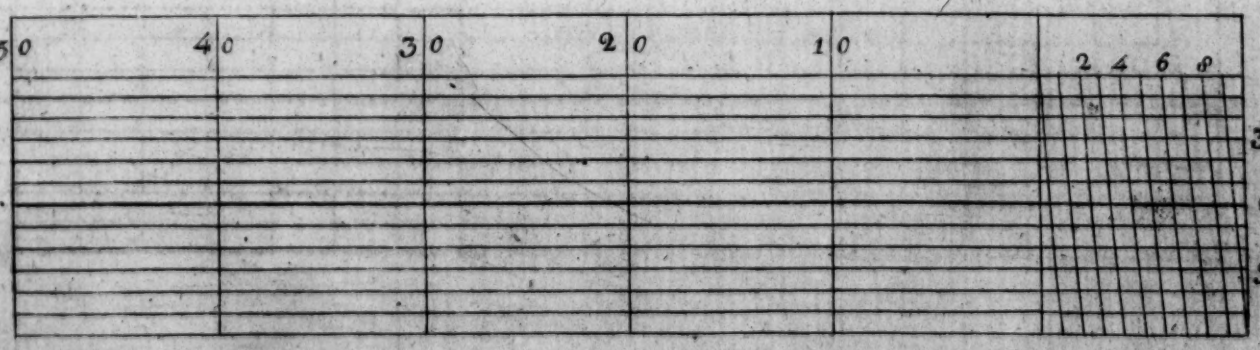
4 = 1



5 = 1



8 = 1

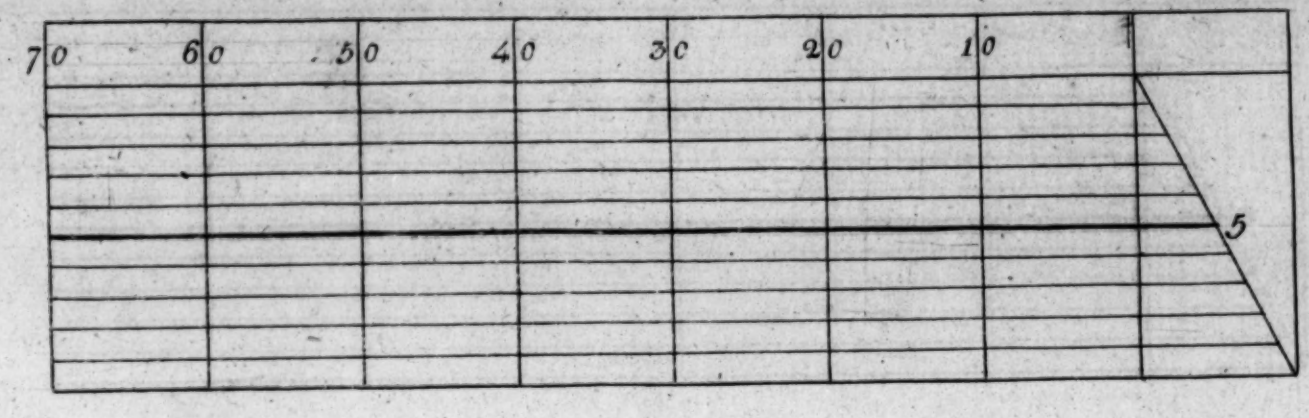


12 = 1

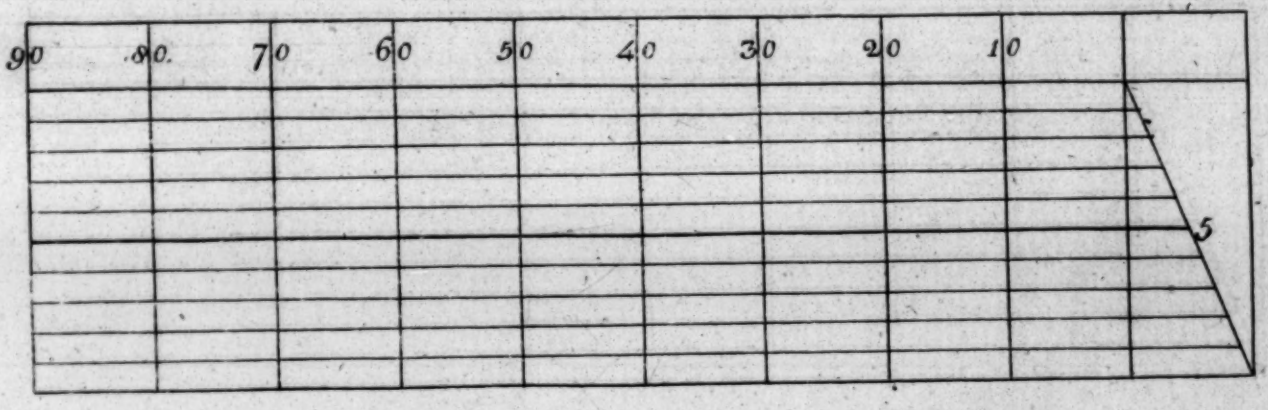


Pl. 63.

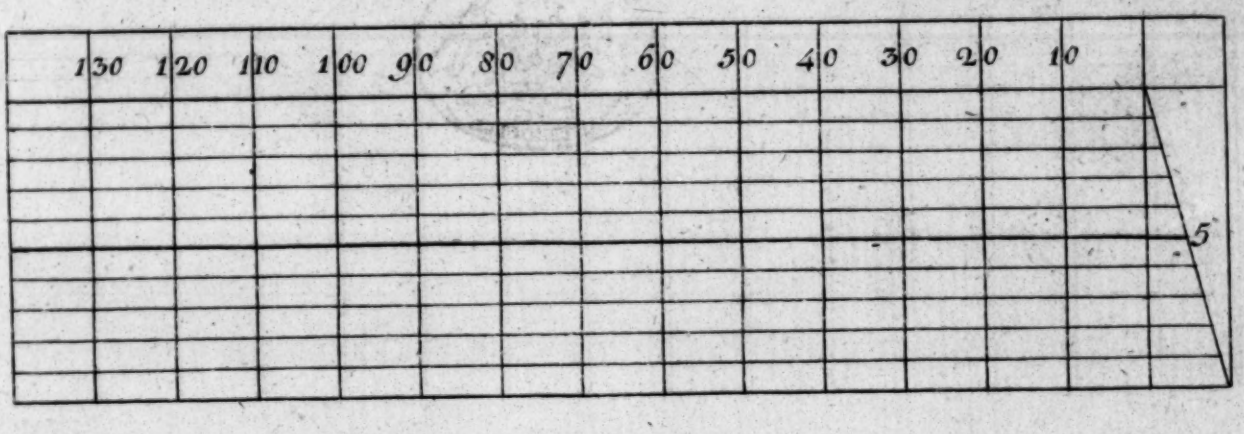
Ft. I
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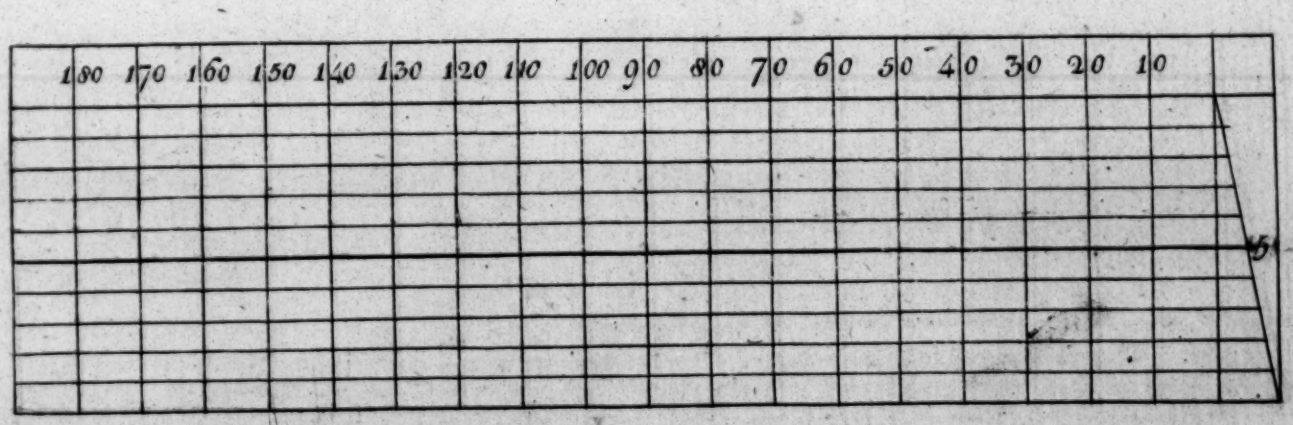
20 = 1



30 = 1



40 = 1



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